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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. EU088610790US

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☐ *Additional inventors are being named on the ______ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Interface For SATPS Systems

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Direct all correspondence to

☐ Customer Number ______ *Type Customer Number here* → *Place Customer Number Bar Code Label here*

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 97

☐ CD(s), Number

☐ Drawing(s) *Number of Sheets*

☐ Other (specify)

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant claims small entity status See 37 CFR 1.27.

☑ A check or money order is enclosed to cover the filing fees

☐ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number

☐ Payment by credit card. Form PTO-2038 is attached

FILING FEE AMOUNT ($): $80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government

☑ No

☐ Yes, the name of the U S Government agency and the Government contract number are ______

Respectfully submitted,

SIGNATURE [signature]

Date 08/14/2002

TYPED or PRINTED NAME Francisco A. Rubio-Campos

REGISTRATION NO. *(if appropriate)* 45,358

Docket Number CT02001USV

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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PTO/SB/17 (10-01)
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FEE TRANSMITTAL for FY 2002

Patent fees are subject to annual revision

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Complete if Known	
Application Number	
Filing Date	08/14/2002
First Named Inventor	Chang et al.
Examiner Name	
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Attorney Docket No	CT02001USV

METHOD OF PAYMENT

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	740	201	370	Utility filing fee	
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	80.00

SUBTOTAL (1) ($) 80.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0.00

**or number previously paid, if greater, For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1 129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1 129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0.00

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Signature				Date	08/14/2002

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U.S. Express Mail No.: EU088610790US
Filing Date: August 14, 2002

PATENT
EG Matter No. CT02001USV
149-US-P1

INTERFACE FOR SATPS SYSTEMS

BACKGROUND OF THE INVENTION

[0001] 1. **Field of the Invention**

[0002] This invention relates generally to the field of wireless communications. In particular, the invention relates to a method and apparatus for interfacing Satellite Positioning Systems ("SATPS") devices to different platforms independent of aides or protocols emanating from the platforms

[0003] 2. **Related Art**

[0004] The worldwide utilization of wireless devices such as two-way radios, portable televisions, Personal Digital Assistants ("PDAs") cellular telephones (also known a "mobile phones"), satellite radio receivers and Satellite Positioning Systems ("SATPS") such as Global Positioning Systems ("GPS"), also known as NAVSTAR, is growing at a rapid pace. As the number of people employing wireless devices increases, the number of features offered by wireless service providers also increases, as does the integration of these wireless devices in other products.

[0005] As an example, the present trend in the automobile and truck industry is to produce automobiles and trucks that have amplitude modulation ("AM"), frequency modulation ("FM"), phase modulated ("PM"), short-wave ("SW") and single-side band ("SSB") radios, mobile phones, GPS receivers, digital radios (also known as digital audio broadcasting "DAB" systems) and satellite radios (also known as digital satellite radios,

or "DSRs," that receive programming from service providers such as, for example, Sirius Satellite Radio, XM Satellite Radio, Orbit Satellite Television and Radio Network, and WorldSpace Corp.) The recreational ship, boat and airplane industries are also following the same trend as the automobile and truck industry. Additionally, integration in wireless devices is occurring with the mobile phone industry integrating GPS capabilities within the mobile phones to meet the Enhanced 911 (also known as "E911") services mandated by the United States Congress.

[0006] As these wireless devices are integrated into products such as automobiles, ships, boats, airplanes, motorcycles, other transportation products and mobile phones, the cost and complexity of producing these products also increases along with the space requirements with a vehicle. Therefore, a goal of these industries includes producing these products with integrated wireless devices that have the highest performance at the lowest implementation cost.

[0007] As in many other areas of electronics, in order to minimize the implementation cost, retain a desired performance, and reduce component size, designers usually attempt to maximize the level of integration, minimize the complexity and minimize any adjustments that may be required (such as tuning). Unfortunately, the radio frequency "RF," intermediate frequency "IF," and baseband portions of a wireless device are usually the most difficult to implement with high levels of integration, reduced complexity and minimal, or no, tuning. Additionally, in order to allow the radio sections of a mobile telephone handset to communicate with the GPS receiver section of the handset an interface is need that allows for signal information to be properly

communication between the GPS receiver and the radio sections. This is additionally true if the GPS receiver and/or radio sections desire aiding between the different sections.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0008] A typical Satellite Positioning Systems ("SATPS") such as Global Positioning System ("GPS") system has approximately 12 satellites that may be visible at any one time to a wireless device. Global Positioning System or "GPS" means any system utilizing satellites and/or land-based communications devices for providing or enabling the determination of a location of the wireless device on the earth, for example but not limited to: NAVSTAR, GLONASS, LORAN, Shoran, Decca, or TACAN.

[0009] GPS is an example of a satellite based navigation system that may be utilized by GPS portion of the combined GPS and radio system ("CGRS") to pinpoint its location on earth. The array of GPS satellites transmits highly accurate, time coded information that permits CGRS to calculate its exact location in terms of latitude and longitude on earth as well as the altitude above sea level. The GPS system is designed to provide a base navigation system with accuracy to within 100 meters for non-military use and greater precision for the military.

[00010] The space segment of the GPS system is a constellation of satellites orbiting above the earth that contain transmitters, which send highly accurate timing information to GPS receivers on earth. The fully implemented GPS system consists of 21 main operational satellites plus three active spare satellites. These satellites are arranged in six orbits, each orbit containing three or four satellites. The orbital planes form a 55° angle

with the equator. The satellites orbit at a height of 10,898 nautical miles (20,200 kilometers) above earth with orbital periods for each satellite of approximately 12 hours.

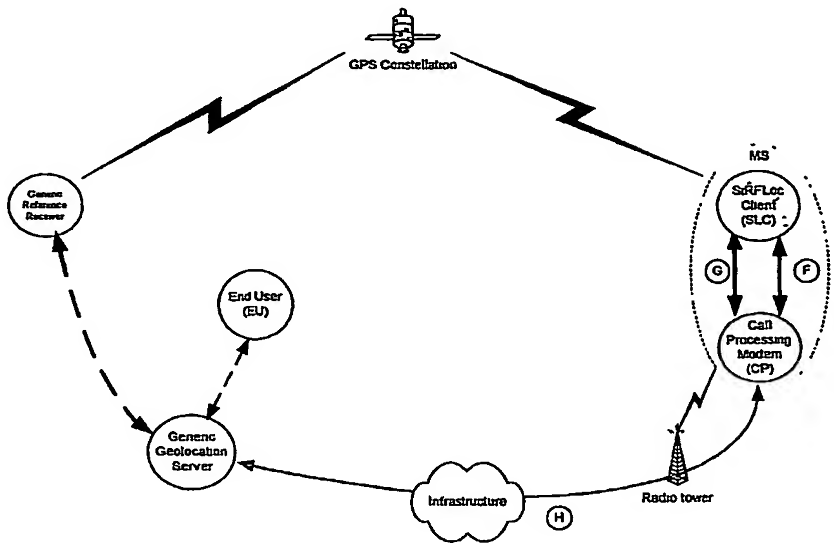
[00011] Each of the orbiting satellites contains four highly accurate atomic clocks. These provide precision timing pulses utilized to generate a unique binary code (also known as a pseudo random or pseudo noise "PN" code) that is transmitted to earth. The PN code identifies the specific satellite in the constellation. The satellite also transmits a set of digitally coded ephemeris data that completely defines the precise orbit of the satellite. The ephemeris data indicates where the satellite is at any given time, and its location may be specified in terms of the satellite ground track in precise latitude and longitude measurements. The information in the ephemeris data is coded and transmitted from the satellite providing an accurate indication of the exact position of the satellite above the earth at any given time. A ground control station updates the ephemeris data of the satellite once per day to ensure accuracy.

[00012] A typical GPS receiver configuration is designed to pick up signals from three, four, or more satellites simultaneously. The GPS receiver decodes the information and, using the time and ephemeris data, calculates the approximate position of the GPS receiver. The GPS receiver contains a processor that performs the necessary calculations and may output a decimal display of latitude and longitude as well as altitude on the handset. Readings from three satellites are necessary for latitude and longitude information. A fourth satellite reading is required in order to compute altitude.

[00013] The invention encapsulates all the geolocation protocol implementation in the Call Processing, ("CP") and communicates SATPS, more specifically, Global Positioning

System ("GPS") assistance information to and position or other geolocation results (example: pseudoranges, code phase etc.) from the client, also known as the ("SLC"), through a geolocation protocol independent interface.

[00014] The "face-value" advantages of the present invention, enables the GPS portion of the system to be free of implementation of multiple protocols. Each protocol, when using the present invention, can be implemented as a translator from the platform protocol to the independent protocol used by the GPS chip, thereby allowing seamless availability of geolocation information as the mobile handsoff from one wireless communication standard to another, thereby changing the way in which it receives assistance data and transmits position or other geolocation results from the Call Processor (phone) to a remote aiding server. Each unique geolocation protocol (IS-817, IS-801 etc.) for all different air interfaces used in various places around the world can now be served by a single GPS implementation without resetting or reconfiguring the GPS subsystem, where the present invention is used to translate the GPS information to the protocol used by the communication system subscribed by each customer, and vice versa.



[00015]

[00016] Figure 1 - Wireless Mobile Position System Architecture – AI3 Architecture

[00017] Geolocation protocols are Application Protocols

[00018] Contrary to many protocol stack levels, Geolocation protocols are application protocols, which means they deal with the semantics (meaning) of the message, not by merely transporting data from one side to the other side, without error and eliminating swapping or repetition as in a TCP-IP stack.

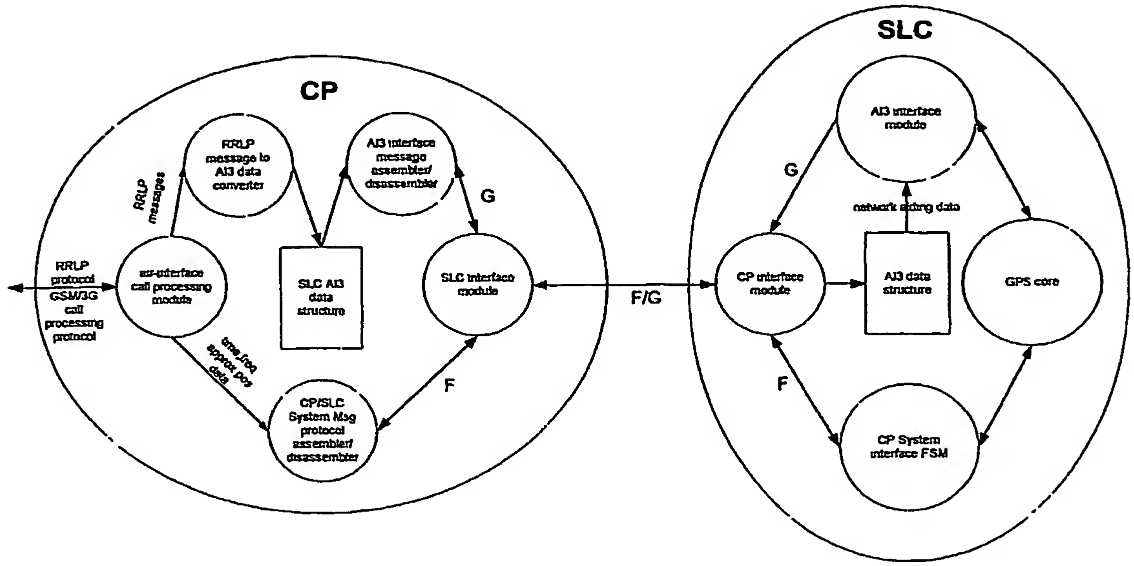
[00019] Therefore, the entity which handles the protocol (e.g., decides to request some data) needs to know what those data will be used for, and the meaning of every parameter exchanged over the protocol (needs to know the GPS side). Any attempt to separate the decision to request information from the actual creation of the message which requests the information will most likely be inadequate. As such, the implementer of the Geolocation protocol has to be GPS "savvy" to do a correct job.

[00020] Current Implementation

[00021] In the present current implementation, the strategy is intimately merged into the air-interface Finite State Machine ("FSM"). This means that the state in which the FSM is currently is imposed by the current knowledge of the contents of the GPS memory, and that the decision to send a request message to complete some incomplete GPS information is built-in in the FSM itself. There is currently no way to separate the strategy from the protocol handling.

[00022] Handset Design Concept with AI3 for GSM/3GPPThe purpose of the AI3 concept is to make the SLC based handset to work with any geolocation air-interface protocol for network aided data with or without SiRFLoc Server. The current AI3 architecture supports the network aiding with Ephemeris data or Almanac data.

[00023] Figure 2 shows the high level architecture of AI3 to be implemented inside the RRLP based handset. The CP shall communicate with the SLC via a RS232 link and hardware lines (for the time and frequency transfers) as described in Figure 2. The F and G are two separate logical channels for the RS232 interface. The G interface is designed to pass the AI3 aiding data to SLC. The rest of the aiding data will be passed to SLC via the F interface. On the SLC side, the F interface is a standard SiRFLoc client interface and the G interface is transparent to any standard air-interface protocols. The CP shall generate the AI3 data via an "RRLP message to AI3" converter. The AI3 data will be packed into the G message format via an AI3 interface message handler before passing to SLC via the RS232 link. The CP may obtain the time, and reference location data from an appropriate RRLP air-interface messages and pass them to SLC via appropriate "F" interface messages.



[00024]

[00025] Figure 2 – General concept of AI3 architecture for RRLP/GSM based handset.

[00026] <u>How to split strategy from protocol handling</u>

[00027] The present invention implements, at design time, per piece of assistance information an "information dependency tree" which would work on the "barebones" or "GPS core" native GPS aiding interface.

[00028] There is a dependency tree per type of assistance information necessary for the GPS core. As an example, we might have a tree description per each piece of following assistance information, necessary to preset the search:

[00029] Doppler, Doppler uncertainty, Code offset, Code offset uncertainty.

[00030] The leaves of each tree are elementary GPS information, which can be already available at the SLC (i.e. found in the non-volatile internal memory), or can be retrieved through the geolocation protocol.

[00031] The stems of the leaves are a mathematical expression which converts a set of elementary information into a single information of lower level (example: ephemeris of satellite PRN #5, plus current GPS time allows to compute satellite position at the given time)

[00032] The strategy algorithm identifies what are the "information leaves" with available information (from memory), identifies several ways to get to the root of the tree (final desired information), and for every possible way to go to the root, identifies:

[00033] How many pieces of information are missing and necessary to go to the root.

[00034] How much computation steps it necessitates to go to the root information.

[00035] How much cost (time, air-interface bandwidth) is associated with the retrieval of this piece of information through the protocol.

[00036] The least costly method is chosen and attempted. If failed, the second less costly is attempted, etc, until the information is retrieved for the system.

[00037] The cost function associated with the dependency trees is very dependent on the geolocation protocol.

[00038] The next step is to "map" those identified GPS elementary parameters into one or several different message requests (there is a chance that all parameters will not be returned in the same message), and finally to trigger the proper request messages.

[00039] Some GPS elementary parameters might not be available through the given interface, and the cost function can then be assigned to infinity, to prevent the algorithm from trying to obtain such information.

[00040] In the returned message, the received parameters have to be extracted, identified with the GPS elementary parameters, reformated into the format expected by the barebones interface. In some cases, some mathematical transformation will have to be applied by the customer, e.g., approximate position given in ECEF and requested in Lat/Lon/Alt by the generic interface.

[00041] The independence of the generic interface with the messages and formats of the Geolocation protocol is obtained at the expense of: that the geolocation protocol implementer needs to have a significant expertise about GPS technology(to map Geolocation messages into generic parameters), and needs to know very well how the strategy algorithms work (to define the cost functions). There is still a protocol (interactive) to develop to let the CP know what are the required parameters, and how to return the results to the SLC. The best way to eliminate this protocol is to implement this idea only in a single processor, handling both CP and SLC functionnalities. The protocol is thus reduced to function interfacing.

[00042] <u>Possible Approaches to the Air Interface Independent Interface</u>

[00043] If the customer wishes to implement the geolocation protocol within the CP system, the customer must implement all of the parts of the protocol that are currently implemented today in the SLC as a single Finite State Machine:

[00044] -Message coding/decoding,

[00045] -Protocol management (sends/receives messages, manages timeouts/retries...), and

[00046] -Strategy (what messages to request to the server, how to report the results to the GPS receiver).

[00047] The coding/decoding and protocol management are usually well defined in the geolocation standard protocol documents, and would be no problem to the user.

[00048] The real issue is the strategy implementation, which is highly dependent on what the customer knows about the GPS processing section and the GPS environment. Typically, only the SLC has the context in which the GPS assistance is requested, e.g., knows what the stored ephemeris, last computed position, RTC time, etc. are, and thus is typically the only device that can implement the strategy part. There are several approaches to alleviate that serious problem:

[00049] 1)- The interaction between SLC and CP is eliminated by using an interface instead of a protocol. Such a system typically is a very inefficient interface, and has limited performance.

[00050] 2)- The interaction between SLC engine and CP is eliminated by "canning" the requests. This must been agreed at design time between the CP manufacturer and the GPS manufacturer. The customer protocol module will systematically send the same subset of requests picked from the geolocation protocol. Once the protocol interactivity is broken, this solution has exactly the same performance problems as solution 1).

[00051] 3)- The strategy is implemented in the SLC and the CP just sends the requests decided in the SLC.

[00052] Here are the possible ways to make this connection between protocol and strategy (on two physically separate processors, which are connected by a serial link)

[00053] a)-create a "meta-protocol" for every request possible in the geolocation protocol, create a corresponding message in the meta-protocol. Completely lose the air-interface independency, as the "meta-protocol" mimics every message in the initial geolocation protocol. Create another layer of protocol which does not add any advantage, and increases the complexity of the implementation. It is much simpler to send and receive the geolocation messages themselves.

[00054] b)-create a protocol based on "generic" GPS assistance interface every bit and piece of information the GPS receiver might need is catalogued in a generic list, like "ephemeris parameters of the satellite PRN #5", "ionospheric information." The list can be very long and redundant, as there are quite a few ways to split this information. The format conversion from geolocation protocol into generic assistance information must be done by the customer, who will need some level of GPS expertise. Some GPS-specific mathematical transformations could also be required to be implemented by the customer, which makes the generic interface less desirable.

[00055] To answer the request of having the customer in charge of the geolocation protocol the present invention envisions at least three technically viable solutions:

[00056] 1) Implement a generic interface, without interaction, using a very limited number of parameters. Such an approach is easily implemented, but suffers from lack of extension at later phases or upgrades to the system.

[00057] 2) Have the customer implement their own code inside the SLC, as in the SDK, according to the current GPS receiver architecture.

[00058] 3) Have the customer implement their own code inside the SLC, but using "generic assistance" with the bare-bones GPS core, but inside the SLC. To develop the generic interface, we need to implement at least one geolocation protocol completely in the SLC (preferably a complicated one), as it is the only way to learn the best way to do "generic assistance" with GPS core interface.

[00059] In the case where the customers want to be the "owners" of the geolocation protocol inside the CP, this AI3 could be used between the CP and the SLC.

[00060] It should be usable over a large range of geolocation standards, as it is a reduction to the "most common denominator" of all of them. As it is the most common denominator of quite a few standards, it will typically not be optimized for any of them. It also typically allows only one single form of assistance, e.g., ephemeris. This interface is designed to be used between CP and SLC over a serial connection local to the mobile device. It will be difficult to use such an interface over the airwaves, air as the volume of exchanged information is quite significant.

[00061] AI3 can also be used as a "quick" and sub optimal way to implementation on a large variety of air interfaces and a large range of customers, and can be used to allow the SLC to roam to different networks that have different protocols. For example, the present invention can be used as the "standard roaming" geolocation interface (when the phone is not in is home network), aside from the "main" geolocation protocol.

[00062] Configurations and requests

[00063] The decision to use the AI3 (or another choice) is made by the CP and notified to the SLC by a special "air-interface" code in the session opening message of the "F" interface.

[00064] Implicit assistance

[00065] All implicit assistance (Time transfer, Frequency transfer) is transmitted over the "F" interface as in the past.

[00066] MS approximate position

[00067] If available, transmitted over the "F" interface.

[00068] MS Position report

[00069] The position is returned over the "F" interface

[00070] Number of requested positions

[00071] In the majority of the geolocation interfaces, this is specified in one of the over the air messages. Here, the assumption is that the position is periodically and continuously required until the session is closed (to confirm). The only information exchanged over the "AI3" is the GPS assistance information by a mechanism called the memory mirroring concept.

[00072] "Memory mirroring" concept

[00073] The interface is defined as a large data structure, which will be probably implemented as a memory section. All information present in the interface has a predetermined position in this large structure. To signify the validity of every piece of information, a validity flag is also assigned to every field in this structure.

[00074] The transmission of the information is simply a "read and transmission byte by byte" of the full structure in a predetermined order (MSB first, etc...). The Client side has a similar data structure, and is filled out byte by byte as soon the information comes. A single checksum test is made on the full structure for validating it.

[00075] Reduction of "memory mirroring" message size

[00076] In some cases, not all ephemeris will be valid, and in theory, the message could be shortened by sending only the ephemeris slots actually having valid information. This should be avoided as the memory mirroring mechanism should not be dependent on the meaning of the message.

[00077] A way to accomplish that is to choose the convention of putting all unused fields (including the validity fields) to "0". A simple compression mechanism, sending the number of consecutive bits set to zero, instead of the bits themselves, could be used for the same purpose.

[00078] This mechanism requires the use of a unambiguous special metacharacter, preceding a fixed field indicating a number of repetitions of consecutive bits set to "0" instead of the bits themselves.

[00079] Contents of memory mirroring structure

[00080] This is strictly composed of ephemeris information, and possibly ionospheric parameters, excluding any other type of assistance. Note that some assistance received over the air interface protocol can be delivered to the SLC through the "F" interface (approximate user location for example).

[00081] Duration of transmission of the memory mirroring message

[00082] The size of ionospheric mode is 64 bits, ephemeris data per satellite is 407 bits, num_sv is 8 bits, iono_flag is 1 bit; for 8 satellites the size is 8+1+64+407*8=3329 bits; for 10 satellites is 4143 bits. At 9600 baud, the message is transmitted in less than 0.5 second, which will not impact the TTFF.

[00083] Message Timing, Timeout: Within a few seconds after the Session Opening Notification Message has been returned to the CP, the CP should start to send this structure byte by byte in the predetermined order. If the information is not available at the CP, the structure should be send anyway, with all validity flags to "non valid".

[00084] If the SLC has not received a single character within few seconds (2?) after it returned the Session Opening Notification Message, it will send some type of very simple "NACK" message over the "D" interface, requesting the CP to send the information again. The "NACK" message will be reiterated every (2) seconds until a complete message is received and declared usable, or a Session Closing Request Message is received. At any time, when the information or part of it has been updated in the CP structure, the message can be resent at will by the CP. As it is another "D" interface, no AI3 message can be sent before a Session Opening Request/Response pair, or after a Session Closing Request/Response pair.

[00085] Transport mechanism:

[00086] This is a transport interface already adopted in SLC, including header, payload checksum trailer. A "memory mirroring type" is added in front as an equivalent to "message type", to allow extension of this interface in the future.

[00087] Checksum

[00088] Checksum in the transport mechanism is only for checking the integrity of the structure, not to correct errors. The trivial error mechanism we want to protect from is one missing character.

[00089] The interface of the present invention can be used as a default air interface, which may have some limitations but is always available to the CP. Further, the interface can co-exist with other interfaces as a backup interface should the other interface fail. The Aiding Independent Interoperability Interface (AI3) Interface Control Document is attached as Appendix A.

[00090] The adoption of the interface of the present invention will facilitate the integration of CP and SLC functions on a single processor. In such an environment, the assistance data exchange between CP task and SLC task will be very probably made over a shared memory. The memory structures currently in the CP and SLC sides would be merged in a single structure; the "memory mirroring" mechanism would be simply eliminated, but the writing and reading functions to this shared memory would stay the same.

[00091] The foregoing description of the preferred embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention not be limited by this detailed description.

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AIDING INDEPENDENT INTEROPERABILITY INTERFACE (AI3) Specification

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OVERVIEW

This document defines procedures and messages related to the "Aiding Independent Interoperability Interface" (AI3) between the Call Processor (CP) and the SiRFLoc Client (SLC). The procedures and messages defined in this document are designed to be used in addition to *SiRFLoc Client Interface Control Document* (Ref 2) to support wireless aided mobile positioning services using the SLC.

The following goals were used in developing this document:

- Comply with the existing aiding transport mechanism in Ref 2, hence minimizing the required modifications to Ref 2 to support the AI3;
- AI3 is usable and unique for a large range of geolocation standards.
- The Air-Interface Protocol Stack is implemented by the customer in the Call Processor.

GLOSSARY

2D Position. A two-dimensional (latitude and longitude) position.

3D Position. A three-dimensional (latitude, longitude, and height) position.

Aiding Data. The aiding data provided by the base station to the mobile station for various purposes (e.g., acquisition, location calculation or sensitivity improvement).

Generic Geolocation Server Station. This term refers to the entity in the network which provides aiding (GPS-related or other) information to the SLC, and retrieves the position results. It has different names depending on the cellular platform of interest (PDE for IS801, GMLC for GSM,...)

Call Processor (CP). The dedicated hardware and software to establish and manage a wireless radio connection.

Ephemeris. The ephemeris data are embedded in the GPS Navigation Message. The precise (high accuracy) orbital parameters of one GPS satellite, as transmitted by that satellite in the GPS Navigation Message Subframe 1, 2, and 3. The ephemeris also includes satellite clock correction.

Geolocation. The process of determining a geographic location.

GPS. Global Positioning System.

LSB. Least Significant Bit

Mobile Station (MS). It consists of a CP and a SLC, communicates with the base station and receives GPS signals.

MSB. Most Significant Bit

SiRFLoc Client (SLC). The SiRFLoc GPS section embedded in the mobile station. It is composed of à protocol layer, to dialog with the CP and SLS through the CP, on top of the SiRF GPS core technology (hardware and software).

SV. Space Vehicle or Satellite.

REFERENCES

Ref 1 ICD-GPS-200C, Navstar GPS Space Segment/Navigation User Interfaces, September 1997.

Ref 2 SiRFLoc Client Interface Control Document, Rev 1.6, May 2001.

Ref 3 SiRFLoc Over-the-Air Geolocation Messages Specification, Rev 1.3 , January 2001.

Ref 4 Digital cellular telecommunications system (Phase 2+); Location Services; Mobile Station (MS)- Serving Mobile Location Centre (SMLC), Radio Resource LCS Protocol (RRLP) (GSM 04.31 version 8.1.0 Release 1999).

AI3 FUNCTIONAL ARCHITECTURE

For purposes of this document, the mobile station (MS) consists of a CP and a SLC. The CP refers to the dedicated hardware and software to establish and manage wireless communication with the base station. The SLC refers to the GPS section to receive GPS signals and determine the mobile station geographic location. The SLC can be as a subsystem or integrated as IP. It is composed of the "Aiding Independent Interoperability Interface" layer, to dialog with the CP, on top of the SiRF GPS core technology.

Whereas SiRFLoc encompasses several architectures, one of the architectures in which AI3 interface shall be used is the "Aiding Independent Interoperability Interface Functional Architecture". The CP implements a Geolocation air-interface protocol (from Geolocation Server to CP) and then pass GPS aiding information received from the base station to the SLC, over the AI3 as shown in Figure 3.

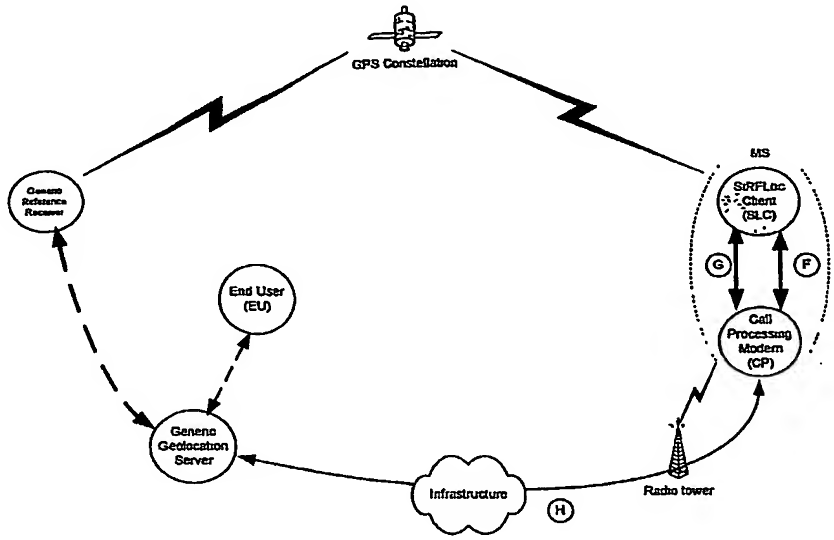


Figure 3-Wireless Mobile Positioning System Architecture-AI3 Architecture

Table 1 describes the interfaces shown in Figure 3. There are different geolocation standards developed for different types of wireless networks; any of them can be the "H" interface.

Table 1-Interface Description

Interface	Functional Entities	Protocol	Description
H	Geolocation Server-CP	Air-interface	Various geolocation standards. Controlled by the CP manufacturer.
F	CP-SLC	SiRFLoc Specific	*SiRFLoc Client Interface Control Document*
G	CP-SLC	SiRFLoc Specific	*AI3-Defined in this document*

The F interface, which is the client system interface between SLC and CP, is defined in Ref 2 document. It acts as a bootstrap protocol, ever present, allowing the CP to choose at run-time how the aiding will be conveyed to the SLC in the aiding encapsulation layer. The CP can choose between an air-interface "H"(case of the end-to-end system architecture) or the AI3 ("G"). It is designed to perform one or more of the following tasks:

- SLC hardware management from the CP (power on/off, reset);
- If available, implicit aiding interface, i.e. time and frequency transfer from network (or from CP real time clock) via the CP, and approximate MS position (implicit from the network, if it does exists);
- Session opening/closing (i.e. notifying the SLC that an air-interface connection has been opened/closed);
- In a dual-mode MS, notifying the SLC what air interface is on, and thus notifying the SLC what set of geolocation air-interface protocol to use to dialog with the SLS;

In the "Aiding Independent Interoperability Interface Architecture", it is the CP developer's responsibility to implement the Geolocation protocol that is used between the Geolocation Server and CP. The "G" interface is used to convey GPS Aiding information received from the base station to the SLC. There is no reason why "G" and "F" cannot be integrated into a single protocol or interface, logical and/or physical.

This document defines the "G" interface. Since there are many existing Geolocation protocols, the "G" interface is designed to be usable over a large range of Geolocation standards and air-interface independent, i.e. it is unique for applicable air-interfaces. The "AI3" is actually a reduction of the applicable Geolocation standards. It will not be optimized for any of them.

The CP sends position request information and network aiding information in AI3 format to SLC through the G interface. In return, the SLC sends position results or error notification to CP though the same interface.

All Geolocation protocols, including SAMPS, GSM, and CDMA, work under the interaction paradigm. The base station sends back only what the mobile station has requested. The strategy to perform the interaction is highly dependent on the knowledge on the SLC processing. Only the SLC can optimally implement the strategy part.

Currently, the AI3 supports only one-way aiding. There is no reason why this cannot be two-way. The interaction between SLC and CP required for performing the interaction strategy, is eliminated by "canning" the requests. The "canned requests" are a subset of requests picked from the

Geolocation protocol at design time and will be systematically sent to the Geolocation Server. No control on the interaction can be applied by the SLC. The CP passes the aiding data through AI3 without any request. The SLC cannot stop it or tailors it. Since the protocol interactivity is broken, the performance won't be optimal.

In one embodiment, AI3 shall be used exclusively between CP and SLC over a serial connection in the mobile station. While it is recommended that AI3 not be used over the air as the volume of exchanged information is quite significant and would adversely impact the Time-To-First-Fix (TTFF), once can use this interchange via a remote connection.

AI3 INTERFACE

Physical Interface between CP And SLC

As shown in Figure 4, the physical interface between the CP and the SLC consists of a RS-232C serial communication link and two hardware lines inside the mobile station.

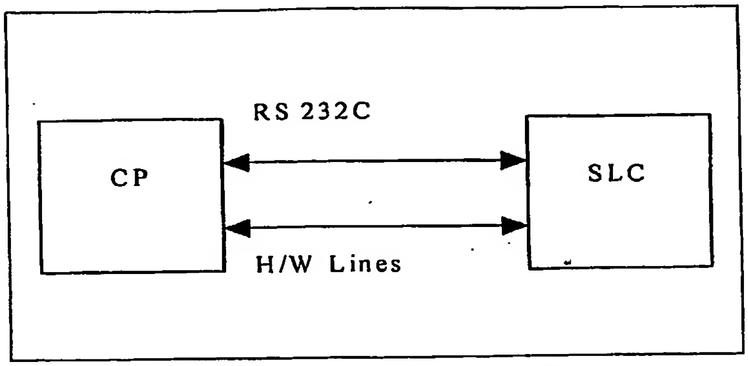


Figure 4-Physical Interface between CP and SLC

The serial link is a bi-directional electrical (ex: TTL level) communication interface and used to exchange messages between the CP and the SLC. In addition, there can be other hardware line/s utilized for other type of aiding, ex: time and frequency transfer.

Common Transport Mechanism

Generic Packet Format

The existing transport mechanism in Ref 2 is used to transport the AI3 packets. The TYPE FIELD shall be "0x01", corresponding to either an "Air-Interface Message" or an "AI3 message".

To Switch to AI3 interface in Session Opening Request message, the CP shall notify the SLC that it shall send the aiding data in "AI3" by using the appropriate value in "SESSION_OPEN_REQ_INFO" format as described in Ref 2.

It is to note that, aside from the "AI3", the CP and SLC can support other air-interfaces that can be activated at run-time using the appropriate value for the "SESSION_OPEN_REQ_INFO" field.

AI3 Packet Structure

The AI3 segments defined here shall be sent in the *PAYLOAD* field as shown in following table:

Table 2-AI3 Packet Structure

HEADER	LENGTH	LOGICAL CHANNEL	PAYLOAD		CHECKSUM	TERMINATOR
			MSG_ID	SEGMENT		
2 Bytes	2 Bytes	1 Byte	1 Byte	M Bytes	2 Bytes	2 Bytes

MSG_ID Message Identifier.

SEGMENT Message Segment.

AI3 Segment Format

An AI3 Segment includes three fields. The first byte presents the total number of segments used for transporting the AI3 message. The second byte is the segment index starting with 1. The last field is the compressed AI3 data with a maximum size of 1016 bytes.

Table 3- AI3 Segment Format

PAYLOAD			
MSG_ID	SEGMENT		
	NUM_OF_SEGMENTS	SEGMENT_INDEX	COMPRESSED_AI3_DATA
1 Byte	1 Byte	1 Byte	<= 1016 Bytes

NUM_OF_SEGMENTS Number of segments

The AI3 data may be sent in several segments. This field indicates the total number of segments for a complete set of AI3 data. 0 is an invalid number.

SEGMENT_INDEX Segment Index

The value of this field is the sequence number of the AI3 data segment transported by this message. Its range is from 1 to 255. The last message of the AI3 data set has SEGMENT_INDEX equal to NUM_OF_SEGMENTS; 0 is an invalid number for this field.

COMPRESSED AI3 DATA Compressed AI3 data

This field is a section of the compressed AI3 data.

Maximum Packet Size, Maximum Segment Size

Each PAYLOAD field in a AI3 packet has a maximum total size of 1019 Bytes, and therefore, only transports a maximum of 1018 bytes in the SEGMENT field .

As every segment has a 2 bytes header, if the size of the compressed AI3 data is larger than 1016 Bytes, it needs to be segmented; each segment shall be sent sequentially in a separate packet.

Message Compression Method

The size of some of the messages is quite large. At 9600 baud rate, it takes about 2.14 seconds to transmit the AI3 Data message with 8 visible ephemeris and without Almanac data.

Actually, not all Data in a message will be valid, which means there are a lot of fields set to 0. A simple data compression algorithm will significantly reduce the size of the data to be transmitted. The data compression algorithm shall be a lossless type of compression and manipulate byte streams without regard to what the bytes mean. It should also be easily implemented and quickly executed.

The data compression algorithm applied to all AI3 messages is a "packbits" method, which is a very simple and popular variant of run-length encoding method. A run is a group of identical consecutive characters. Each run is coded as a 2-byte header that describes what kind of run it is and its length, and one or more bytes that contains the data. In all cases, the header is split into two sections: its MSB describes whether it is a literal run (uncompressed) or a fill run (compressed), and the next 15 bits specify the length of the run, as shown below.

Table 4-RLL Compression-Header Format

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RUN_INDICATOR_BIT 0 = uncompressed 1 = compressed	LENGTH (bytes)														

A literal run is a run of literal bytes (i.e. bytes which are stored rather than compressed). In this case, the RUN_INDICATOR_BIT is 0 and the lower 15 bits specify the length of the run of the literal bytes. The literal bytes are then encoded directly after this header.

A fill run is a sequence of bytes where all the bytes are identical. In this case, the RUN_INDICATOR_BIT is 1 and the lower 15 bits specify the length of the run. The header is followed by the byte which should be copied the given number of times. One example is given as follows to show how the data compression algorithm works.

Origin byte stream: 0x01 0xFF 0x00 0x89 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x12
After compression: 0x00 0x04 0x01 0xFF 0x00 0x89 0x80 0x07 0x00 0x12

The data decompression algorithm is also very simple. The SLC shall get the RUN_INDICATOR_BIT and the length. If the RUN_INDICATOR_BIT is 0, the next *LENGTH* bytes are just copied. If the RUN_INDICATOR_BIT is 1, the next coming byte shall be copied *"LENGTH"* number of times. For example:

Compressed data: 0x80 0x08 0x00 0x00 0x05 0x44 0x00 0x01 0x66 0x45
After decompression: 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x44 0x00 0x01 0x66 0x45

Special rules for compression/decompression implementation

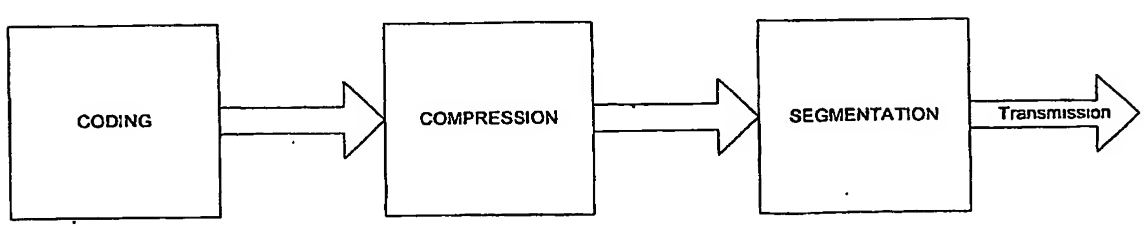
No matter their size, all transmitted messages shall be compressed.

To simplify the implementation, on transmission side, the message preparation shall be done in the following sequence:

- -Message Coding
- -Compression
- -Segmentation

Figure 5-Coding/Compression/Segmentation Sequence

TRANSMISSION SIDE



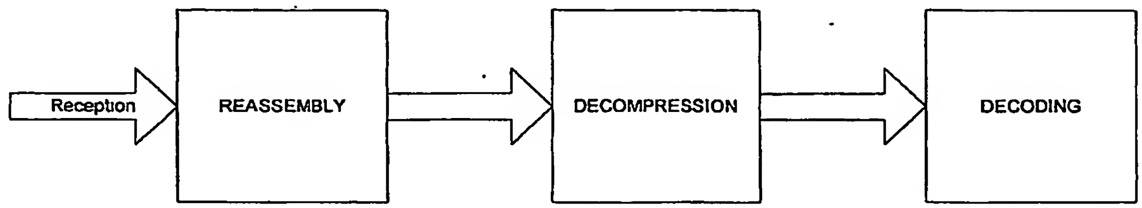
For compatibility, the message processing at the receiving side shall be done in the reverse order:

- -Segment validation and reassembly
- -Decompression

-Decoding

Figure 6-Reassembly/Decompression/Decoding Sequence

RECEPTION SIDE



Also for ease of implementation reasons, the compression applied at the transmission does not need to be optimal. The decompression on the receiving side must accommodate this non optimal compression method. The compression is non optimal because:

-only a sequence of consecutive "0x00" can be coded in a compressed run.
-all consecutive "zero" bytes do not need to be grouped in a single compressed run.
-"zero" bytes can be coded in a non compressed mode as well.
-a new header can be introduced anywhere in the sequence (for example to independently compress every logical section).
-a "run" (or span between two consecutive RLL headers) can overlap two segments.

-Even if the compression is not optimal, the compressed message size should not go over "size of original message plus 2 bytes".

Example of worst case of allowed compression (compressed size=original size plus two):

Original message: 0x01 0x00 0x00 0x00 0x00 0x10 0x20 0x30 0x40 0x50
Compressed message : 0x00 0x0A 0x01 0x00 0x00 0x00 0x00 0x10 0x20 0x30 0x40 0x50

Example of forbidden compression case (compressed size> original size+2):

Original message: 0x00 0x01 0x00 0x01
Compressed message: 0x00 0x01 0x00 0x80 0x01 0x01 0x00 0x01 0x00 0x80 0x01 0x01 0x00

AI3 Message Definitions

Aside from the ACK/NACK message, All information present in the AI3 data messages has a predetermined position in a large structure. To signify the validity of every piece of information, a validity flag is also assigned to each group of information in this structure. This special arrangement has been chosen to facilitate the conversion of this protocol as a shared memory between tasks on a same processor. For now, the AI3 protocol is specifically designed to be used over a serial link, between two separate processors.

Detailed Message Definitions

Currently, Three AI3 messages, the AI3 Request, AI3 Response and the ACK/NACK message are defined. The following table gives their message identifiers. These messages can be increased if required.

Table 5- AI3 Message ID

Messages	MSG_ID	CP SLC
AI3 Request	0x01	→
AI3 Response	0x02	←
ACK/NACK Message	0x03	←, →

AI3 Request

An AI3 Request is amongst other elements composed of position request information, ionospheric parameters, satellite ephemeris and almanac. In addition, other aiding data received over the air interface protocol can be delivered to the SLC through the "F" interface (for example, approximate user location, time and frequency transfer).

To signify the validity of every piece of information, a validity flag is also assigned to each group of information in this structure.

Some of the AI3 Request message represents information conveyed from the CP to the SLC and is described in Table 6:

Table 6- AI3 Request Message Before Compression

Field	Length (bits)	Scale Factor	Unit
POS_REQ_FLAG	8		
NUM_FIXES	8		
TIME_BTW_FIXES	8	1	Seconds
HORI_ERROR_MAX	8		(See Table 7)
VERT_ERROR_MAX	8		(See Table 7)
RESP_TIME_MAX	8	1	Seconds
TIME_ACC_PRIORITY	8		(See Table 8)
ALM_REQ_FLAG	8	N/A	N/A
IONO_FLAG	8	N/A	N/A (See Table 9]
ALPHA_0	8(1)	2^{-30}	Seconds
ALPHA_1	8(1)	2^{-27}	sec/semi-circles
ALPHA_2	8(1)	2^{-24}	$sec/(semi-circles)^2$
ALPHA_3	8(1)	2^{-24}	$sec/(semi-circles)^3$
BETA_0	8(1)	2^{11}	Seconds
BETA_1	8(1)	2^{14}	sec/semi-circles
BETA_2	8(1)	2^{16}	$sec/(semi-circles)^2$
BETA_3	8(1)	2^{16}	$sec/(semi-circles)^3$

The structure shall include 32 occurrences of the following record of ephemieris parameters:

EPH_FLAG	8	N/A	N/A
SV_PRN_NUM	8	N/A	N/A
URA_IND	8	N/A	N/A
IODE	8	N/A	N/A
C_RS	16(1)	2^{-5}	Meters
DELTA_N	16(1)	2^{-43}	semi-circles/sec
M0	32(1)	2^{-31}	semi-circles
C_UC	16(1)	2^{-29}	Radians

ECCENTRICITY	32	2^{-33}	N/A
C_US	16(1)	2^{-29}	Radians
A_SQRT	32	2^{-19}	$\sqrt{meters}$
TOE	16	2^{4}	Seconds
C_IC	16(1)	2^{-29}	Radians
OMEGA_0	32(1)	2^{-31}	semi-circles
C_IS	16(1)	2^{-29}	Radians
ANGLE_INCLINATION	32(1)	2^{-31}	semi-circles
C_RC	16(1)	2^{-5}	Meters
OMEGA	32(1)	2^{-31}	semi-circles
OMEGADOT	32(1)	2^{-43}	semi-circles/sec
IDOT	16(1)	2^{-43}	semi-circles/sec
TOC	16	2^{4}	Seconds
T_GD	8(1)	2^{-31}	Seconds
AF2	8(1)	2^{-55}	sec/sec^2
AF1	16(1)	2^{-43}	sec/sec
AF0	32(1)	2^{-31}	Seconds

ALM_DATA_FLAG	8	N/A	N/A
ALM_WEEK_NUM	16	N/A	N/A
The structure shall include 32 occurrences of the following record of almanac parameters			
ALM_VALID_FLAG	8	N/A	N/A
ALM_SV_PRN_NUM	8	N/A	N/A
ALM_ECCENTRICITY	16	2^{-21}	dimensionless
ALM_TOA	8	2^{12}	Seconds
ALM_DELTA_INCL	16(1)	2^{-19}	semi-circles
ALM_OMEGADOT	16(1)	2^{-38}	semi-circles/sec.
ALM_A_SQRT	24	2^{-11}	meters$^{1/2}$
ALM_OMEGA_0	24(1)	2^{-23}	semi-circles
ALM_OMEGA	24(1)	2^{-23}	semi-circles

ALM_M0	24(1)	2^{-23}	semi-circles
ALM_AF0	16 (1)	2^{-20}	Seconds
ALM_AF1	16 (1)	2^{-38}	sec/sec

Table 7- Horizontal/Vertical Error

Values	Position Error (in meters)
0x00	<1meter
0x01	<5 meters
0x02	<10 meters
0x03	<20 meters
0x04	<40 meters
0x05	<80 meters
0x06	<160 meters
0x07	No Maximum
0x08 – 0xFF	Reserved

Table 8- Time/accuracy priority

TIME_ACC_PRIORITY	Description
0x00	No priority imposed
0x01	RESP_TIME_MAX has priority over HORI_ERROR_MAX/VERT_ERROR_MAX
0x02	HORI_ERROR_MAX/VERT_ERROR_MAX has priority over RESP_TIME_MAX
0x03 – 0xFF	Reserved

Table 9-ALM_REQ_FLAG Description

Value	Description
0	No almanac request (default)
1	Report flash Almanac age (message sent back even with no position)
2	Request Almanac Collection from SV

3	Report Almanac Update Status
4 - FF	Reserved

AI3 Response message

Amongst other things the SLC reports MS position results and Almanacs reference time in the format specified in Table 10.

Table 10 - AI3 Response Message Before Compression

Field		Length(bits)
POS_RESULTS_FLAG		8 bits
POSITION_ERROR_ STATUS		8 bits
POS_ACC_MET		8 bits
POSITION MAIN SECTION	POS_TYPE	8 bits
	DGPS_COR	8 bits
	MEAS_GPS_WEEK	16 bits
	MEAS_GPS_SECONDS	32 bits
	MEAS_LAT	32 bits
	MEAS_LONG	32 bits
	OTHER SECTIONS	8 bits
Following sections are always present, but their validity depends on the value of OTHER_SECTIONS		
HORIZONTAL ERROR SECTION	ER_EL_ANG	8 bits
	MAJ_STD_ER	8 bits
	MIN_STD_ER	8 bits
VERTICAL POSITION SECTION	HEIGHT	16 bits
	HEIGHT_STD_ER	8 bits
VELOCITY SECTION	HOR_VEL	16 bits
	HEADING	16 bits
	VER_VEL	8 bits
	VEL_ER_EL_ANG	8 bits
	VEL_MAJ_STD_ER	8 bits
	VEL_MIN_STD_ER	8 bits
	VER_VEL_STD_ER	8 bits

CLOCK CORRECTION SECTION	TIME_REF	8 bits
	CLK_BIAS	16 bits
	CLK_DRIFT	16 bits
	CLK_STD_ER	8 bits
	UTC_OFF	8 bits
POSITION CORRECTION SECTION	NB_SV	8 bits
	Two following fields are repeated 10 times, only the first "NB_SV" fields are valid.	
	SV_PRN	8 bits
	C_NO	8 bits
	INV_WEIGHTS	8 bits
ALM_REF_DATE_FLAG		8 bits
ALM_DATA_STAT	8 bits	
ALM_WEEK_NUM	16 bits	
ALM_TOA	8 bits	

ACK/NACK Message

The ACK/NACK Can be either sent by SLC (in response to a message from CP), or by CP (in response to a message from SLC).

Table 11-ACK/NACK Message format

Field	Length (bits)
ACK/NACK	8

MESSAGE PROCESSING PROCEDURES

General Overview

The AI3 Request and Response are defined as large data structures. Those messages will be probably implemented by using a memory mirroring mechanism. For every message, the same memory structure is defined on the CP and SLC sides.
One set of memory is defined per direction.

The transmission of the information in one implementation is simply a "read, compression, and transmission byte-by-byte" of the full structure on the transmitting side. The same data structure on the receiving side is filled out byte-by-byte as soon the information arrives and is decompressed.

The CP shall send the AI3 Request message at the opening of the "AI3" session, even when the AI3 data structure has not been updated. The SLC shall use the validity flags in the data structure itself to determine what information is relevant. The compression mechanism drastically reduces the transmission time of the empty sections of the message.

In a preferred embodiment, Neither SLC, nor CP shall send any AI3 message before a Session Opening Request/Response pair of "AI3" type, or after a Session Closing Request/Response pair have been exchanged over the "F" interface.

For every message received, an ACK or NACK message is returned, to speed up the repetition of the message if improperly received. This mechanism is intended to be used on a local serial link, and has no strong error detection and correction mechanism. It should not be used over-the-air in any circumstances.

SLC Procedures

SLC Reception Procedures

- Upon receiving an AI3 Request message after an AI3 session is open, the SLC shall examine the received AI3 message. If the AI3 message is transported in several packets, the SLC will need to reassemble the segmented data. After receiving all packets of an AI3 message correctly the SLC shall decompress the reassembled data and copy it to the structure on the SLC side.
- Upon receiving an AI3 message before an AI3 session is open, the SLC shall silently discard the message.
- If a segment data is missing, the whole message shall be discarded.

SLC Transmission Procedure

- Regardless of the time set by MAX_RESP_TIME field found in the AI3 Request, upon completing a position fix, the SLC shall send an AI3 Response providing the position fix, with POSITION_RESULTS_FLAG set to '1' (valid position section) and POSITION_STATUS set to '0' (valid position).
- Upon timeout of the MAX_RESP_TIME field found in the AI3 Request, and no position fix yet, SLC shall send an AI3 response message with POSITION_RESULTS_FLAG set to '1' (valid position section) and POSITION_STATUS set to "Need More Time".
- Upon reaching the end of the GPS search domain, and with no position found, SLC shall send an AI3 response message with POSITION_RESULTS_FLAG set to '1' (valid position section) and POSITION_STATUS set to "No fix available after full search".
- If the SLC needs more Aiding data (Ephemeris only), SLC may send an AI3 response message with POSITION_RESULTS_FLAG set to '1' (valid position section) and POSITION_STATUS set to "GPS Aiding data missing".
- Optionally, and according criteria to be defined on a case by case, the SLC may add an Almanac reference date section in any AI3 Response message. This capability is meant to allow the CP to evaluate the age of the almanacs in the SLC, and possibly to replace them by a newer one, by an AI3 Request message.

CP Procedures

CP Reception Procedures

- Upon reception of an Air Interface Protocol Message (or a group thereof), the CP shall fill (while reformatting if necessary) the relevant fields of the "AI3 data structure" on the CP side, using the received Air-Interface Message information. If an AI3 session is currently open, the CP shall send the AI3 Request message when the information or part of it has been updated in the CP structure without any request.
- Upon reception of an AI3 Response message, the CP shall examine the received AI3 message. If the AI3 message is transported in several packets, the CP will need to reassemble the segmented data. After receiving all packets of an AI3 message correctly the CP shall decompress the reassembled data and copy it to the structure on the CP side.
- Upon receiving an AI3 message before an AI3 session is open, the CP shall silently discard the message.
- If a segment data is missing, the whole message shall be discarded.

CP Transmission procedures

- Within 2 seconds after the Session Opening Notification Message with the SESSION_OPEN_STATUS field set to Session Opening Succeeded is received (See Ref 2), the CP shall start to send the AI3 Request message regardless whether it has valid aiding information or not. The AI3 Request shall be compressed and only the compressed data stream shall be sent to the SLC. If the size of the compressed data stream is larger than the maximum, it shall be segmented into several data packets. The data packets shall be sent sequentially in the order they have been segmented.

Exception procedures:

For an AI3 Request message from CP to SLC:

CP side

-When CP sends an AI3 Request message, it expects an ACK or a NACK back from the SLC, within 3 seconds after transmission of the message.
-If CP does not receive anything within 3 seconds, it shall send again the AI3 Request. It can repeat the sequence up to three times. After the 3 times repetition, the CP shall close the AI3 channel.
-If CP receives a NACK it sends immediately the same message again. After three repetitions, the CP shall close the AI3 channel.

SLC side

-As soon as the SLC receives the message from CP and decodes it properly, it sends an ACK within 3 seconds of the reception. If the message cannot be decoded properly, SLC sends a NACK within 3 seconds.
-If segments of a same message are received out of order, the SLC throws away the segments already received, ignores the remaining segments and sends a NACK within 3 seconds.

For an AI3 Response message from SLC to CP:

SLC side

-When SLC sends an AI3 Response message, it expects an ACK or a NACK back from the CP, within 3 seconds after transmission of the message.
-If SLC does not receive anything within 3 seconds , it sends again the AI3 Response. It can repeat the sequence up to three times. After the 3 times repetition, the SLC shall stop sending the message.
-If SLC receives a NACK it sends immediately the same message again. After three repetitions, the SLC shall stop sending the message.

CP side

-As soon as the CP receives the message from SLC and decodes it properly, it sends an ACK within 3 seconds of the reception. If the message cannot be decoded properly, CP sends a NACK within 3 seconds. After three repetitions, the SLC shall stop sending the message.
-If segments of a same message are received out of order, the CP throws away the segments already received, ignores the remaining segments and sends a NACK within 3 seconds.

Special Procedures

Update Almanac in Flash from Network

This procedure will be followed when the CP has received valid almanac from the network and wants to update the almanac in SLC's flash:

1)-CP sends an "AI3 request message" with ALM_REQ_FLAG set to "0", and ALM_DATA_FLAG set to "1" and valid almanac information in the Almanac section.

2)-SLC stores the almanac data in the RAM as soon as it gets the AI3 request message

3)-When the CP closes the AI3 session from the F interface, SLC transfers almanac information from RAM to FLASH:

- -If the transfer of almanac from RAM to FLASH has been successful, the SESSION_CLOSE_STATUS in "Session Closing Notification message" Close session in F interface will be set to "Session Closed".
- -If the transfer of almanac from RAM to FLASH has failed, the SESSION_CLOSE_STATUS in "Session Closing Notification message" Close session in F interface will be set to "Session Closing Failed".

Update Almanac from SV

This procedure will be followed when the CP wants to force the SLC to collect new almanac and update the almanac in SLC's flash with collected almanac:

1)-CP sends an AI3 request message with ALM_REQ_FLAG set to "2" (Request Almanac Collection from SV), and ALM_DATA_FLAG set to "0" and no Almanac section

2)-Upon reception, SLC will try to collect almanac data from broadcast

3)-To check on the progress, CP periodically sends AI3 request message with ALM_REQ_FLAG set to "3" (Report Almanac Update Status).

Upon reception of the update status request message, SLC shall immediately send and AI3 response message with:

ALM_DATA_STATUS set to "1" if SLC is searching for satellites, and not collecting any NAV message

ALM_DATA_STATUS set to "2" if SLC tracks at least one satellite strong enough to collect data, and is actually collecting data
ALM_DATA_STATUS set to "3" if SLC has gone through a full search sequence and has not found any satellite suitable for data collection
ALM_DATA_STATUS set to "4" if SLC has collected a full almanac

and ALM_WEEK_NUMBER and TOA either from RAM-stored or FLASH-stored almanac according to the table **Error! Reference source not found.**.

4)-When the CP closes the AI3 session from the F interface, SLC transfers almanac information from RAM to FLASH:
-If the transfer of almanac from RAM to FLASH has been successful, the SESSION_CLOSE_STATUS in "Session Closing Notification message" Close session in F interface will be set to "Session Closed".
-If the transfer of almanac from RAM to FLASH has failed, the SESSION_CLOSE_STATUS in "Session Closing Notification message" Close session in F interface will be set to "Session Closing Failed".

Note 1: If no full almanac was collected during the session (and the ALM_DATA_STATUS was never found to "4" during step 3), the SLC won't try to transfer the incomplete almanac from RAM to FLASH. The SESSION_CLOSE_STATUS in the "Session Notification message" will be set to "Session Closed".

Note 2: A full almanac collection cycle will take a little bit less than 13 minutes. The CP should not expect to receive an ALM_DATA_STATUS set to "4" before such a time elapsed since the first time ALM_DATA_STATUS has been found set to "2".

Check Age of Almanac in FLASH

When an AI3 session is open, the CP can check at any time what is the age of the almanac currently in flash.

1)-CP sends an AI3 request message with ALM_REQ_FLAG set to "1", and ALM_DATA_FLAG set to "0" and with no Almanac section

2)-Upon reception of the age of almanac request message, SLC shall immediately send and AI3 response message with ALM_DATA_STATUS set to "0" and ALM_WEEK_NUMBER and TOA from FLASH-stored almanac.

Special Cases

If CP sends an AI3 request message with both POS_REQ_FLAG and ALM_REQ_FLAG set to "1" response will be undefined.

[00092] While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible that are within the scope of this invention.

CLAIMS

What is claimed is:

1. An interface for Satellite Positioning Systems comprising:

a interface;

a radio section on a handset; and

a Satellite Positioning Systems on the handset in signal communication with the radio section via the interface.

Estimated Position Error (EPE)

1. What is EPE?

GPS equations are defined by GPS measurements from four or more GPS satellites and lines of sight to the corresponding GPS satellites (also called satellite geometry). There are variety of errors exist in the GPS measurements and when the GPS equations are solved, these measurement errors are amplified by satellite geometry to give rise to an error in the estimate of position. When an estimator solves GPS equations it also produces an estimate of error in position. This position error estimate is defined as EPE.

The EPE reports the errors in three dimensions (3D) and it can be fully represented by a 3D confidence ellipsoid (an ellipsoid inside which one can expect to find the true position with some levels of confidence). However, it is often convenient to give partial specification of EPE in the local horizontal plane and along the local vertical direction; in the local horizontal plane the EPE is specified by a 2D confidence (or error) ellipse; in vertical direction it is specified by a confidence (or error) interval.

It is to be noted that the EPE is inferred by using a statistical model of measurement errors. At times this statistical model is not a good representation of the measurement errors to which the receiver is subjected in real time and in such cases the EPE is prone to significant uncertainties.

2. How is EPE reported in SiRF receivers?

In SiRF receivers the EPE is reported by parameters of horizontal error and vertical error. For the horizontal error these are (1) confidence ellipse parameters of semi-major axis, (2) semi-minor axis and (3) the acute angle subtended by the semi-major axis with the local north. For the vertical error it is error magnitude (fig. 1). The ellipse is positioned on the estimated position and can be thought of as a region estimate (as against the usual point estimate) of the position in the horizontal plane. The magnitude of the vertical error, when added and subtracted from the estimated position along the vertical line, defines a segment, which can be thought of as an interval estimate of the position along the vertical line. There will be a percentage of chances that the true position may lie inside the ellipse in the horizontal plane and inside the interval along the vertical line depending on the associated confidence level. This is true for each reported position. For example fig. 2 shows two ellipses and two vertical intervals centered at estimated

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Fig. 1: Confidence ellipse in horizontal plane and confidence interval along vertical line

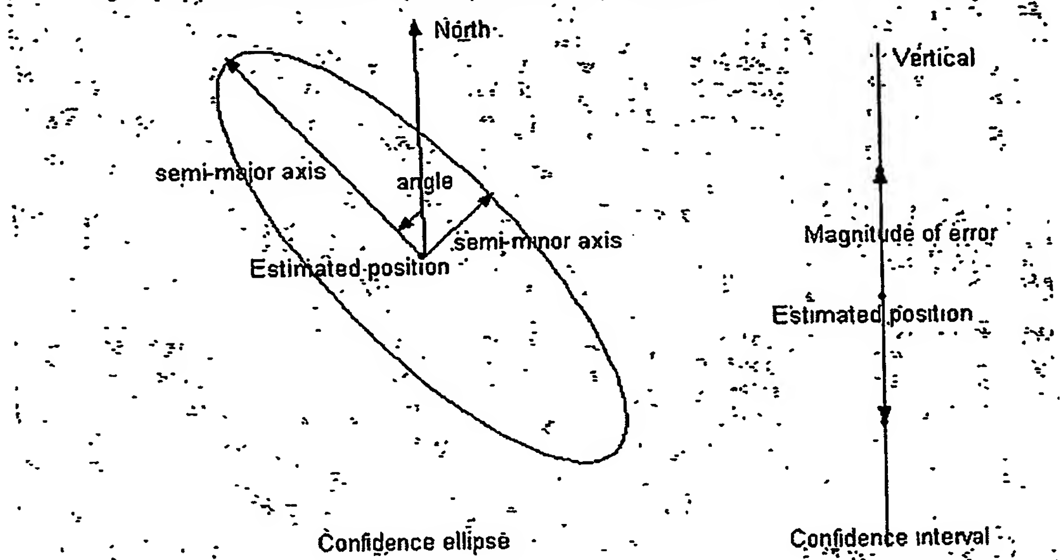
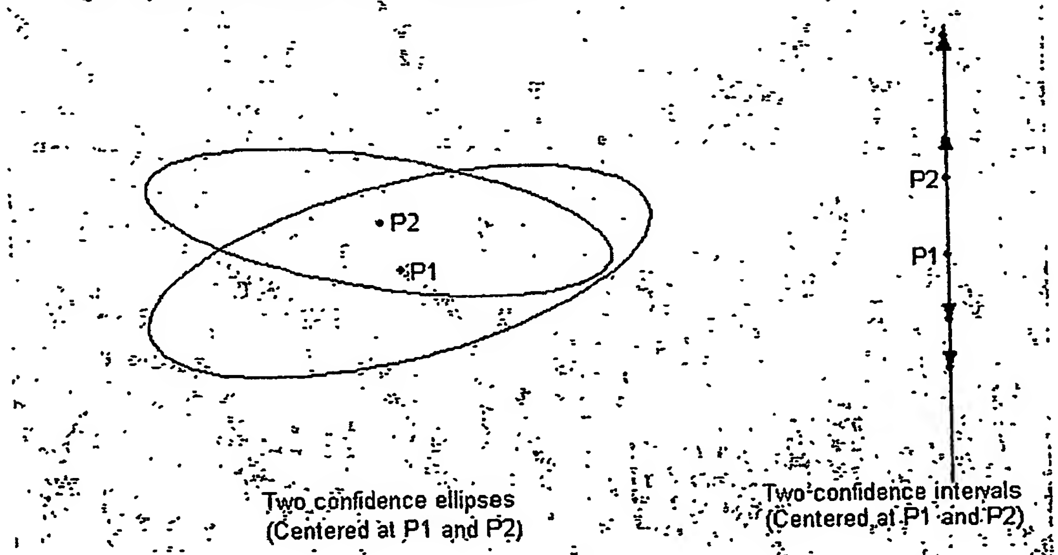


Fig 2 Confidence ellipses and intervals centered at two position estimates (P1 and P2)



positions P1 and P2 (note that even if true position is stationary, the P1 and P2 in general are different). The ellipses may or may not overlap with each other. Similarly the segments may or may not overlap with each other. The orientations and sizes of ellipses and lengths of the intervals depend on satellite geometry and on the parameters of error models used by the estimator, which solves the GPS equations.

3. Confidence levels

Error in estimate of position is a random variable. If random measurement errors have a Gaussian distribution then the error in the estimated position also has Gaussian distribution. This Gaussian distribution is a three dimensional (3D) distribution, which includes the single dimensional (1 D) Vertical Position Error (VPE) random variable and the two dimensional (2D) Horizontal Position Error (HPE) random variable.

The standard deviation of the 1 D VPE is the 1-sigma value of the error. An n-sigma value of the VPE is simply n times its 1-sigma value. Along the vertical line it is expected that the vertical component of the true position is found 68.27% of the time in the +/-1-sigma VPE interval centered at the estimated position, 95.45% of the time in the +/- 2-sigma interval and 99.73% of the time in the 3-sigma interval. The percentage confidence is called confidence level. The corresponding n values (in n-sigma) are called confidence or sigma coefficients. In summary, for the VPE, the relationship between the sigma coefficients and the confidence level are defined as: 1-sigma ⇔ 68.27%, 2-sigma ⇔ 95.45% and 3-sigma ⇔ 99.73%.

For the 2D HPE, the confidence intervals become confidence ellipses and the percentage confidence levels are different from 1D to 2D. In 1D, there is only one line along which the confidence interval is considered. In 2D, there are two axes, say local north axis and local east axis and these two axes specify infinitely many lines in the horizontal plane and infinitely many standard deviations and intervals; with standard deviation along a line depending on the inclination of the line. It turns out that the locus of the end points of all such intervals is an ellipse; it is called as the confidence ellipse. Along the line of semi-major axis the length of the interval is maximum, whereas along the semi-minor axis it is minimum. If 1-sigma intervals are considered then one gets 1-sigma ellipse, if 2-sigma intervals are considered then one gets 2-sigma ellipse and so on. Semi-major axis of n-sigma ellipse is n times semi-major axis of 1-sigma ellipse, so is the case with semi-minor axis and angle orientation of n-sigma ellipse is the same as angle orientation of 1-sigma ellipse. In the horizontal plane it is expected that the horizontal projection of the true position to be found 39.4% of the time in the 1-sigma HPE ellipse centered at the estimated position, 86.5% of the time in the 2-sigma ellipse and 98.9% of the time in the 3-sigma ellipse. It is not necessary to have n in n-sigma as integer. One can specify percentage confidence to get corresponding sigma coefficient, for example, for 95% confidence level, 1D

[redacted]

sigma coefficient is 1.96 and 2D sigma coefficient is 2.45. Table 1 shows different sigma coefficients; it also includes the 3D case.

Table 1 – Signal Coefficients vs. Designed Confidence Level

Sigma Coefficients			DESIRED CONFIDENCE LEVEL (%)
1D Case Standard Deviation	**2D Case Standard Ellipse**	**3D Case Standard Ellipsoid**	
0.01	0.14	0.33	1
0.06	0.32	0.59	5
0.14	0.46	0.76	10
0.25	0.66	1.00	20
0.52	1.00	1.36	39
0.68	1.18	1.54	50
1.00	1.52	1.88	68
1.64	2.15	2.50	90
1.96	2.45	2.79	95
2.58	3.04	3.37	99
2.81	3.26	3.58	99.5

The confidence percentage gives a percentage of times components of true position lie inside the HPE ellipse or the VPE interval centered at estimated position. Equivalently, this is nothing but percentage of times components of an estimated position lie inside HPE ellipse or VPE interval to be centered at true position.

4. EPE verification on a SiRF receiver

The confidence percentage gives a means of verification of EPE. For a specified confidence percentage, a sample of large size is gathered and the percentage of times the true position lies inside the HPE ellipse and inside the VPE interval is determined. If these percentages are close to the specified percentage confidence levels within some tolerance then the EPE is verified. The question to be answered is: How large should be the sample size or equivalently how large should be the duration of data collection?

It is hopeless to try to evaluate performance of the EPE by collecting data for just few hours. This is because that some measurement error components have a very long latency period (period required for the error to average out to zero). Notable among these components are errors due to the residual signal propagation delays in ionosphere and troposphere, and in satellite clock and

ephemeris. These are the long-term error components as against the short-term error components such as the receiver measurement noise and the multi-path. Table 2 shows the 1-sigma values of these various error components along with their orders of latency periods under the open sky and non-reflective environment conditions.

Table 2 – 1 Sigma Values and Latency Period for Position Error Components

Error component	1-sigma value in meter	Order of latency period
Receiver noise	0.5	Seconds
Multi-path	1	Minutes,
Residual ionosphere	4	Days
Residual troposphere	0.2	Days
Satellite clock	2	Days
Satellite ephemeris	2	Days

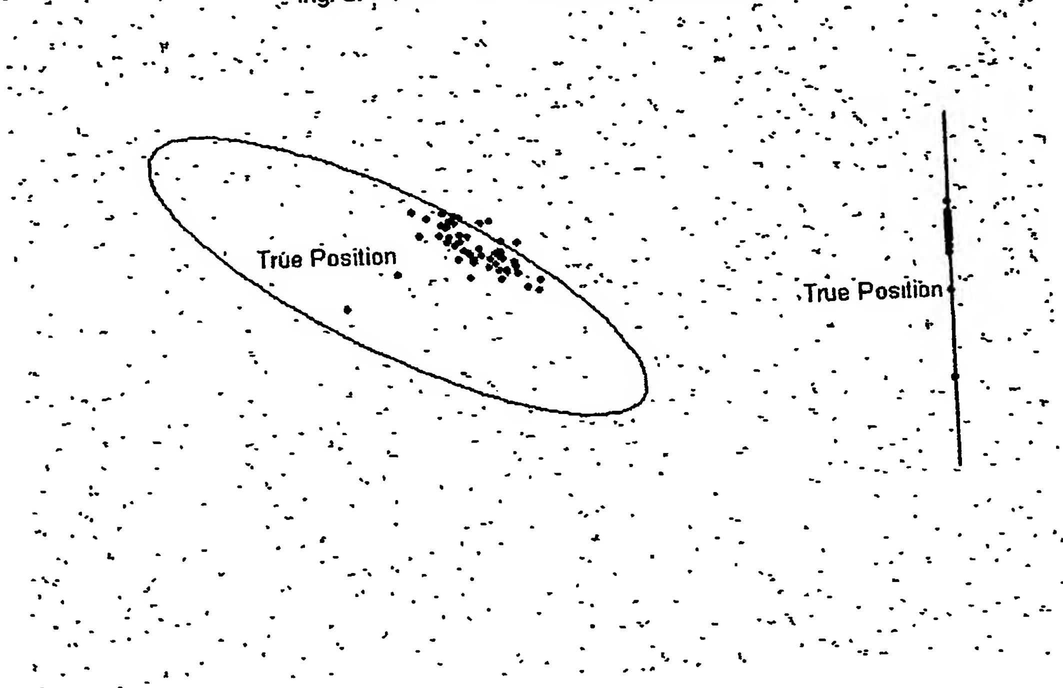
The long-term errors when viewed over a short period appear as biases rather than random fluctuations around zero. If over a period, the satellite geometry and signal conditions are almost constant for a stationary receiver then the HPE ellipse and VPE interval will also remain constant. In this case, it is possible to construct the HPE ellipse and VPE interval to be centered at the true position. It can be seen from fig. 3 that the errors due to long term error components in the measurements show a cloud of points away from the true position. If the HPE ellipse and VPE interval remain constant then this cloud will be spread evenly after a long time. However it is not possible to see this effect because the HPE ellipse and VPE interval will not remain constant due to changes in satellite geometry and the signal conditions but the scenario provides help in visualization of the effects of long term error components in the measurements.

The above scenario also provides some insight into the difficulty of the EPE verification due to the change in satellite geometry. If there are distinct satellite geometries and in the period of verification and some or all geometries do not have even spreads of the corresponding error clouds then the percentage values determined for the HPE and VPE are prone to uncertainty.

Yet another difficulty in the EPE verification arises due to the mismatch between the statistical modeling of the measurement errors used in EPE calculation and the actual measurement errors to which the receiver is actually subjected in real-time. For example, the EPE is calculated based on nominal multi-path measurement error modeling but the actual receiver might be subjected to considerable multi-path.

Finally the EPE calculation is based on the assumption that the errors of both the long term measurement and the short term measurement have a Gaussian distribution. Deviation from this assumption can occur in the real-time test scenario and can cause further uncertainties in the EPE.

Fig. 3. Cloud of errors away from true position



5. SiRF EPE computations

The EPE parameters are obtained from covariance matrix of the position error. This covariance matrix has two parts; the first part is a prediction from previous navigation history; the second part is a function of instantaneous satellite geometry and measurement error statistics. The satellite geometry is defined by the line of sights between the receiver antenna and the satellites that are used in navigation solution. The measurement error statistics is defined by variances of different components of the measurement errors.

The covariance matrix is formed in the local coordinate frame of north, east and down axes. The square root of diagonal element corresponding to the down axis defines magnitude of the vertical error. The sub-matrix corresponding to the north and east axes defines the horizontal position error ellipse. The normalized eigenvectors of this sub-matrix define the orientation of the semi-major and semi-minor axes and hence define the angle of inclination with respect to the local north. The square roots of the corresponding eigenvalues define the lengths of semi-major and semi-minor axes. Some description on the EPE computation in SiRF receiver can be found in the Appendix E of SiRFstar II SDK software manual.

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1 Scope

This document is to guide the customer's CP software implementer to design the IS801 to AI3 protocol translation layer. To identify which messages in the IS801 are relevant (request and response), and how to map them into the AI3 and F interface.

The recommendation to be presented in this document can be implemented even by a non-GPS specialist.

This document only presents a recommended implementation for the customers to implement the AI3 architecture inside the CP software, but by no means represents the only implementation approach.

2 System Overview

The mobile station consists of a CP and a SLC. The CP refers to the dedicated hardware and software to establish and manage wireless communication with the base station. The SLC refers to the GPS section to receive GPS signals and determine the mobile station geographic location. It is composed of the "Aiding-Independent-Interoperability-Interface" layer, to dialog with the CP, on top of the SiRF GPS core technology.

Whereas SiRFLoc encompasses several architectures; the only one for which AI3 interface shall be used is the "Aiding Independent Interoperability Interface Architecture". The CP implements the Geolocation air-interface protocol (from Geolocation Server to CP) and then passes GPS aid information received from the base station to the SLC, over the AI3 as shown in Figure 1

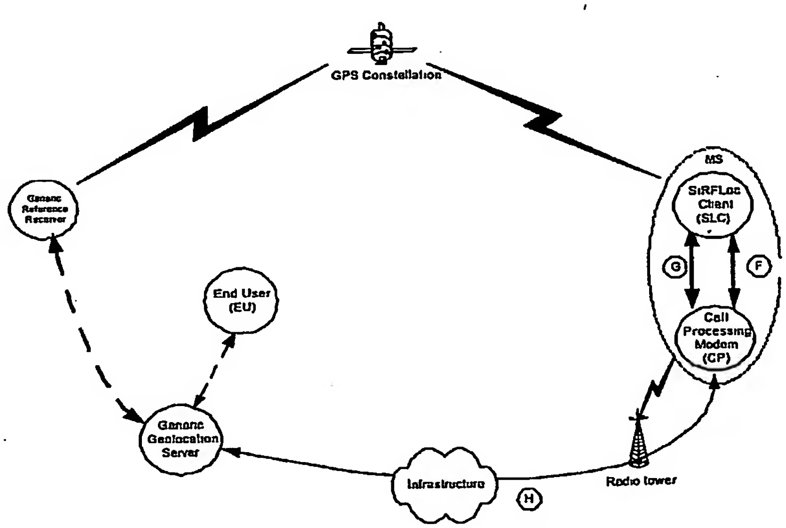


Figure 1 - Wireless Mobile Position System Architecture – AI3 Architecture

Table 1 describes the interfaces shown in Figure 1. There are different geolocation standards developed for different types of wireless networks; anyone can be the "H" interface.

Table 1 Interface Description

Interface	Functional Entities	Protocol	Description
H	Geolocation Server-CP	Air-interface	Various geolocation standards. Controlled by the CP manufacturer.
F	CP-SLC	SiRFLoc Specific	*SiRFLoc Client Interface Control Document*
G	CP-SLC	SiRFLoc Specific	*SiRFLoc AI3 Interface Control Document*

The F interface, which is the client system interface between SLC and CP, is defined in *SiRFLoc Client Interface Control* Document. It acts as a bootstrap protocol, ever present, allowing the CP to choose at run-time between an air-interface (case of the end-to-end system architecture) or the AI3. It is designed to perform the following tasks:

- SLC hardware management from the CP (power on/off, reset);
- If available, implicit aiding interface, i.e. time and frequency transfer from network (or from CP real time clock) via the CP, and approximate position (from the network, if it does exists);
- Session opening/closing (i.e. notifying the SLC that an air-interface connection has been opened/closed);
- In a dual-mode MS, notifying the SLC what air interface is on, and thus notifying the SLC what set of geolocation air-interface protocol to use to dialog with the SLS;
- Interfaces locally with the CP to allow the user to locally trigger a geolocation, and to report the position for display or usage at the MS;
- Convey the position results to the CP.

In the "Aiding Independent Interoperability Interface Architecture", it is the CP developer's responsibility to implement the Geolocation protocol that is used between the Geolocation Server and CP. The G interface is used to convey GPS aid information received from the base station to the SLC.

This ICD defines the G interface. Since there are many existing Geolocation protocols, the G interface is designed to be usable over a large range of Geolocation standards and air-interface independent, i.e. it is unique for applicable air-interfaces. The "AI3" is actually a reduction of the applicable Geolocation standards. It will not be optimized for any of them.

Since the "G" interface will be always used together with the F interface, all information already accessible over the "F" interface is not duplicated in this AI3 interface. This prevents a lot of confusion created by the message duplication It also simplifies the AI3, as only the air interface information is sent over the AI3.

All Geolocation protocols, including SAMPS, GSM, and CDMA, work under the interaction paradigm. The base station sends back only what the mobile station has requested. The strategy to perform the interaction is highly dependent on the knowledge on the SLC processing. Only the SLC can optimal implement the strategy part.

For ease of use, the AI3 supports only one single form of aiding - ephemeris aiding. The interaction between SLC and CP required for performing the interaction strategy, is eliminated by "canning" the requests. The "canned requests" are a subset of requests picked from the Geolocation protocol at design time and will be systematically sent to the Geolocation Server. No control on the interaction can be applied by the SLC. The CP passes the aid data through AI3 without any request. The SLC cannot stop it or tailors it. Since the protocol interactivity is broken, the performance won't be optimal..

AI3 is an interface, not a protocol. There is a fundamental difference between an interface and a protocol. The *protocol* is an interactive process, where the information is explicitly requested and explicitly answered. Only the information really needed is requested. The mechanism of error detection and request for repetition is quite sophisticated. On the other hand, the *interface* does not imply any interaction between the two interfaced entities. All information has to be part of the message. There is no need for a sophisticated error correction scheme, and the size of the message can be quite large.

The AI3 shall be used exclusively between CP and SLC over a serial connection in the mobile station. It shall not be used over the air as the volume of exchanged information is quite significant.

3 Revision History

Revision	Date	Description	Editor
Revision 1.0	November 13, 2000	Initial official version	John Zhang, Steve Chang
Revision 1.1	January 3rd,2001	-Corrected SV_PRN_NUM conversion formula -Corrected ALT to HEIGHT conversion formula in 9.1 4b -Corrected GPS time	John Zhang, Lionel Garin

		to TIME_REF_CDMA conversion in 8.4.1 -Corrected HEIGHT(Position Results Message) to HEIGHT(IS801) conversion in section 8.4	

4 Glossary

2D Position. A two-dimensional (latitude and longitude) position.

3D Position. A three-dimensional (latitude, longitude, and height) position.

Aiding Independent Interoperability Interface (AI3). Generic aiding interface between CP and SLC, independent from the actual Geolocation protocol between Geolocation Server and CP.

Aiding Data. The data provided by the base station to the mobile station for various purposes (e.g., acquisition, location calculation or sensitivity improvement).

Generic Geolocation Server Station. This term refers to the entity in the network which provides aid (GPS-related or other) information to the SLC, and retrieves the position results. It has different names depending on the cellular platform of interest (PDE for IS801, GMLC for GSM,...)

Call Processor (CP). The dedicated hardware and software to establish and manage a wireless radio connection.

Ephemeris. The ephemeris data are embedded in the GPS Navigation Message. The precise (high accuracy) orbital parameters of one GPS satellite, as transmitted by that satellite in the GPS Navigation Message Subframe 1, 2, and 3. The ephemeris also includes satellite clock correction.

Geolocation. The process of determining a geographic location.

GPS. Global Positioning System.

ICD. Interface Control Document.

Mobile Station (MS). It consists of a CP and a SLC, communicates with the base station and receives GPS signals.

SiRFLoc Client (SLC). The SiRFLoc GPS section embedded in the mobile station. It is composed of a protocol layer, to dialog with the CP and SLS through the CP, on top of the SiRF GPS core technology (hardware and software)

SV. Space Vehicle or Satellite.

5 References

Ref 1 - ICD-GPS-200C, Navstar GPS Space Segment/Navigation User Interfaces,

September 1997

Ref 2 - SiRFLoc Client Interface Control Document, Rev 1.3, January, 2001

Ref 3 – Aiding Independent Interoperability Interface Control Document, Rev 1.0, October 30, 2000

Ref 4 - TIA/EIA/IS-801 Position Determination Service Standard for Dual-Mode Spread Spectrum Systems, October 15, 1999

6 Aiding Data and Their Logical Channels

Table 2 summarizes the aiding data to be required by SLC for MS position computation in the network aided operation mode. Among them, the Ephemeris data and MS Position Request Parameters will be obtained via the IS-801 protocol messages and need to be converted into the AI3 data structure before passing to the SLC via the G interface channel. The SLC will obtain the remaining data via the F interface.

The approximate MS position data can be obtained either via an IS-801 message or implicitly via an IS-95 message. The CP will get very precise GPS time from the BS via the IS-95 Sync Channel Message. The GPS time of SLC will be synchronized with the GPS time of CP via the time transfer method as described in Ref 2. The crystal frequency of SLC will be synchronized with the CP clock frequency via the frequency transfer method as described in Ref 2.

Table 2- Aiding data source for SLC

Data Type	Source	Logical Channel
MS Position Request Parameters	IS801 message: Request Location Response (BS to MS)	G[AI3]
Ephemeris	IS801 message: Provide GPS Ephemeris (BS to MS)	G (AI3)
Approximate MS Position	IS801 message: Provide Base Station Almanac (BS to MS) OR IS-95 Implicit Aiding: Paging Channel "System Parameter Message" (BS to MS)	F (client system)
GPS time	IS-95 Implicit Aiding: Sync Channel "Sync Channel Message" (BS to MS) AND Time Transfer method	F (client system)
Frequency	IS-95 Implicit Aiding: a method to find out the	F (client

	frequency offset between BS and CP. AND Frequency Transfer method	system)

7 IS-801 Handset Design Concept with AI3

The purpose of the AI3 concept is to make the SLC based handset to work with any geolocation air-interface protocol for network aided data without SiRFLoc Server. The current AI3 architecture only supports the network aiding with Ephemeris data.

Figure 2 shows the high level architecture of AI3 to be implemented inside the IS-801 based CDMA handset. The CP shall communicate with the SLC via a RS232 link and hardware lines (for the time and frequency transfers) as described in Ref 2. The F and G are two separate logical channels for the RS232 interface. The G interface is designed to pass the AI3 aiding data to SLC. The rest of the aiding data will be passed to SLC via the F interface. On the SLC side, the F interface is a standard SiRFLoc client interface and the G interface is transparent to any standard air-interface protocols. For the IS-801 CP, the AI3 data will be generated via an "IS-801 message to AI3" converter. The AI3 data will be packed into the G message format via an AI3 interface message handler before passing to SLC via the RS232 link. The CP shall obtain the time, location and frequency data from appropriate air-interface messages (see Table 2). The location data will be passed to SLC via a "F" interface message (Approximate MS Position Response message) as described in Ref 2. The time and frequency data will be passed to SLC via the time and frequency transfer methods as described in Ref 2.

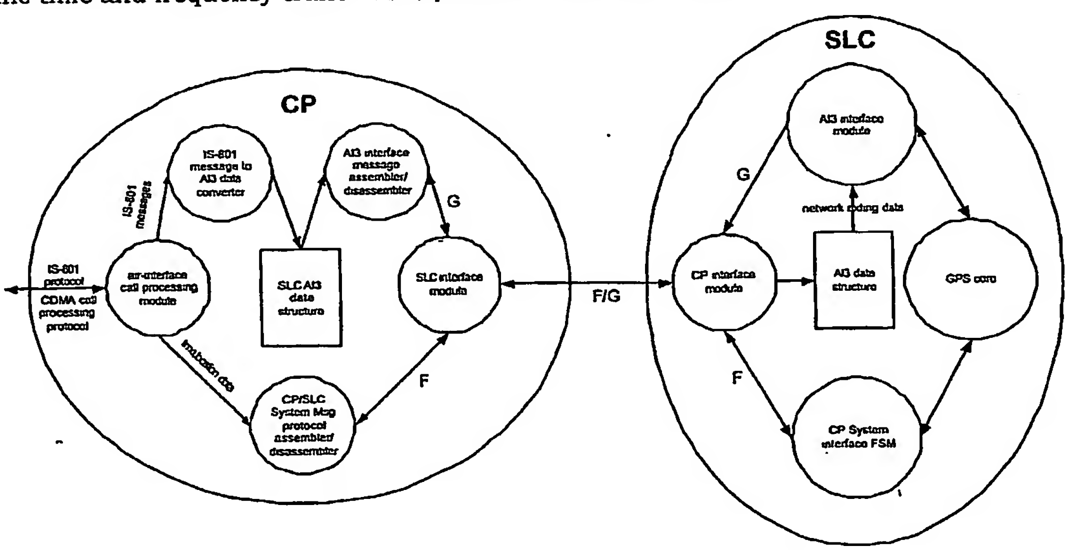


Figure 2 – AI3 Architecture in the CDMA handset

The AI3 data structure contains information on ionospheric, satellite ephemeris and the MS position request parameters. All of these data are byte oriented. The AI3 data

structure needs to be reset to 0 after the CP established a communication link with the BS.

7.1 Source of Aiding Data

7.1.1 Approximate MS Position

The BS position can be used as the approximate MS position. There are two ways to get the BS position data:

1. IS-95 implicit message

   The IS-95 Paging Channel "System Parameter Message" contains the BS position data of longitude and latitude. Since the altitude data is not available in this message, therefore the altitude of the approximate MS position will be set to 0.

2. IS-801 protocol messages

   The CP may also get the BS position data via the IS-801"Provide Base Station Almanac" message. This message contains sufficient data, which can be used to compute the longitude, latitude and altitude of the BS. In this method, the CP will need to send the IS-801 "Request Base Station Almanac" message before the PDE can respond with the "Provide Base Station Almanac" message. This requires additional message handling compared to the IS-95 implicit method.

7.1.2 Location Request Parameters

The IS-801 " Request Location Response" message provides data to compute the number of fixes and time between fixes for AI3 location request parameters. Other location request parameters will be set to values as described in section 8.4.

7.1.3 Ephemeris Data

The IS-801 "Provide GPS Ephemeris" message provides all data to be converted to the ephemeris data for AI3.

7.1.4 GPS Time

To reduce the GPS time uncertainty, the SLC shall synchronize the GPS clock with the CDMA system clock via the time transfer method as described in Ref 2. The CP shall synchronize the handset clock with the CDMA system time, which can be obtained from the CDMA Sync Channel "Sync Channel Message".

7.1.5 Frequency

To reduce the GPS frequency uncertainty, the SLC shall synchronize the GPS clock with the CP and BS clock via the frequency transfer method as described in Ref 2.

7.2 Process of Aiding Data

The CP call processing software shall handle the communication with the BS for network aiding data via the IS-801 and IS-95 message protocols. This section presents the general description for processing the aiding data. Section 9 provides the detailed description of the method to convert the data from IS-801 messages to AI3 structure.

7.2.1 Process of AI3 Data

The AI3 Data consist of MS position request parameters as well as the ephemeris aiding data. The CP may compute the MS position request parameters by using the number of position fixes data to be retrieved from the IS-801 "Request Location Response" message. The CP shall generate the ephemeris aiding data in AI3 format by retrieving the compressed ephemeris data from the IS-801 "Provide GPS Ephemeris" message. The CP shall store the MS position request parameters and the ephemeris aiding data into the AI3 data structure.

7.2.2 Process of the Approximate MS Position Data

The CP may use the BS position data as obtained from the IS-95 "System Parameter Message" during the MS Idle State and used it as the approximate MS position. Due to the lack of altitude information of the BS in the IS-801 "System Parameter Message", the CP shall set the altitude of the approximate MS position to 0.

The CP may choose to obtain the BS position data from the IS-801 "Provide Base Station Almanac" message. By choosing this method, the CP needs to send the IS-801 "Request Base Station Almanac" message during the MS System Idle State or MS Control on the Traffic Channel State. Comparing to the implicit IS-95 method, this method requires the processing of two IS-801 messages and with time delay – later than MS Idle State. Among the multiple BS coordinates found in the "Base Station Almanac" message, the CP shall pick upthe BS with which it has the direct radio connection as the reference BS for the approximate MS position.

7.2.3 Process of the GPS Time Data

The CP uses the CDMA system time as obtained from the IS-95 "Sync Channel Message" as the CP time. The CP sends timing information to SLC via the time transfer method as described in Ref 2.

7.2.4 Process of the Frequency Data

The CP shall synchronize its' clock frequency with the SLC GPS frequency via the frequency transfer method as described in Ref 2.

7.3 Transfer of Aiding Data

The CP shall send the AI3 data to SLC via the G interface "AI3 Data Message ". The G interface is described in Ref 3. The CP shall send the approximate MS position, time and frequency transfer data via appropriate F interface messages. The F interface is described in Ref 2.

7.4 Summary of IS-95 and IS-801 Messages for AI3 Application

Table 3 IS-95 and IS-801 Messages for AI3 Application

Messages	Type		Purpose
	IS-95	IS-801	
Sync Channel Message	BS to CP		Provide the CDMA system time (GPS based).
System Parameter Message	BS to CP		Provide BS position for approximate MS position.
Request MS Information (see Ref 4, section 4.2.4)		PDE to CP	Ask the CP capability
Provide MS Information (see Ref 4, section 3.2.4.2)		CP to PDE	Tell PDE that MS is capable to compute the MS location for GPS Autonomous and Ephemeris Aiding mode.
Request Base Station Almanac (see Ref 4, section 3.2 4.1)		CP to PDE	Request for BS position information.
Provide Base Station Almanac (see Ref 4, section 4.2.4.2)		PDE to CP	Provide BS position information for approximate MS position.
Request Location Response (see Ref 4, section 4.2.4)		PDE to CP	Ask for location result and specify number of position fixes.
Request GPS Ephemeris (see Ref 4, section 3.2.4.1)		CP to PDE	Request PDE to provide Ephemeris data.
Provide GPS Ephemeris (see Ref 4, section 4.2.4.2)		PDE to CP	Provide MS with Ephemeris data.
Provide Location Response (see Ref 4, section 3.2.4.2)		CP to PDE	Provide MS location result to PDE.

8 IS-801 Messages from CP to PDE

To provide the AI3 based location service, the CP shall set appropriate values to certain data fields in the IS-801 messages as described in this section. When the CP receives the position result from the SLC via the F interface, it shall convert the position result into IS-801 message format to be sent to PDE.

8.1 Provide MS Information

In response to the IS-801"Request MS Information" message sent from PDE, the CP shall set the REQ_PAR_RECORD of the IS-801 "Provide MS Information" message as follows:

1. GPS_ACQ_CAP and LOC_CALC_CAP of the RESP_PAR_RECORD shall be set to the values described below.

GPS_ACQ_CAP (12 bits) - Bit 4 (GPS Ephemeris) and bit 7 (GPS Autonomous Acquisition Capable) shall set to '1', other bits shall set to '0'. The bit definitions are defined in Table 3.2.4.2-3 of Ref 4.

2. LOC_CALC_CAP (12 bits) - Bit 5 (Location Calculation Capable using Ephemeris) and bit 7 (Autonomous Location Calculation Capable) shall set to '1', other bit shall set to '0'. The bit definitions are defined in Table 3.2.4.2-4 of Ref 4.

8.2 Request Base Station Almanac

If the CP chooses to obtain the approximate MS position via the IS-801 BS Almanac data, then the CP shall set the REQ_PAR_RECORD of the IS-801 "Request Base Station Almanac" message as follows:

1. EXT_BS_ALM (1 bit) – set to 1.

8.3 Request GPS Ephemeris

The CP shall send the IS-801 "Request GPS Ephemeris" message to obtain the Ephemeris aiding data. The CP shall set the REQ_PAR_RECORD of the IS-801 "Request GPS Ephemeris" message as follows:

1. AB_PAR_REQ (1 bit) – set to 1.

8.4 Provide Location Response

After receiving the "F" interface "Position Result" message from the SLC, the CP shall convert the position result data into the IS-801 "Provide Location Response" message as follows:

1. TIME_REF_CDMA(14 bits)

CP shall convert GPS time to CDMA system time. The GPS time is defined by the MEAS_GPS_WEEK and MEAS_GPS_SECONDS of the "F" interface "Position Result" message. The MEAS_GPS_WEEK is an extended GPS week number and the

MEAS_GPS_SECONDS is the number of elapsed time since the beginning of the current GPS week, in an unit of 1/1000 seconds. The CDMA system time is defined in 1.2 of TIA/EIA-95-B. The TIME_REF_CDMA shall be set to (t/50) mod 16384 as defined in IS801, where t is CDMA system time in frames.2 LAT(25 bits)

LAT = scale_factor_meas_lat x MEAS_LAT(Position Result message)

LAT is in unit of $180/2^{25}$ and MEAS_LAT is in the unit of $180/2^{32}$, therefore

$$scale\_factor\_meas\_lat = (180/2^{32})/(180/2^{25}) = 1/2^{7};$$

Note: the 32 bits computation result need to be converted to 25 bits by take the 7 MSBs out.

3. LONG(26 bits)

LONG = scale_factor_meas_long x MEAS_LONG(Position Result message).

LONG is in unit of $360/2^{26}$ and MEAS_LONG is in the unit of $360/2^{32}$, therefore

$$scale\_factor\_meas\_long= (360/2^{32})/(360/2^{26}) = 1/2^{6};$$

Note: the 32 bits computation result need to be converted to 26 bits by take the 6 MSBs out.

4. LOC_UNCRTNTY_ANG(4 bits), LOC_UNCRTNTY_A(5 bits), LOC_UNCRTNTY_P (5 bits)

If the Bit 0 (LSB) of the OTHER_SECTIONS (Position Result message) is equal to '0'(No horizontal error section in the data), then

LOC_UNCRTNTY_ANG = 0

LOC_UNCRTNTY_A = '11111' (Not computable)

LOC_UNCRTNTY_P = '11111' (Not computable)

Otherwise (the Bit 0 (LSB) of the OTHER_SECTIONS (Position Result) is equal to '1')

The LOC_UNCRTNTY_ANG is in the unit of 5.625 degrees and with the range of from 0 to 84.375 degree. The ER_EL_ANG(Position Result message) is in the unit of 0.75 degrees and with a range from 0 to 179.25 degrees. Therefore

scale_factor_ang = 0.75/5.625 = 0.1333;

If ER_EL_ANG < 120 (90 degree) then

LOC_UNCRTNTY_ANG = scale_facter_ang x ER_EL_ANG

If ER_EL_ANG >= 120 (90 degree) then

LOC_UNCRTNTY_ANG = scale_facter_ang x (ER_EL_ANG – 120);

If ER_EL_ANG < 120 (90 degree)

LOC_UNCRTNTY_A = MAJ_STD_ER(Position Result message)

LOC_UNCRTNTY_P = MIN_STD_ER(Position Result message)

If ER_EL_ANG >= 120 (90 degree)

LOC_UNCRTNTY_A = MIN_STD_ER(Position Result message)

LOC_UNCRTNTY_P = MAJ_STD_ER(Position Result message)

The conversion from MIN_STD_ER and MAJ_STD_ER to LOC_UNCRTNTY_P and LOC_UNCRTNTY_A are based on Table 23 and Table 24 of Ref 2 and Table 3.2.4.2-10 of Ref 4. First the MIN_STD_ER and MAJ_STD_ER is converted to a number in an unit of meters by using Table 23 and Table 24 of Ref 2 and then mapping those numbers to a five-bit LOC_UNCRTNTY_P and LOC_UNCRTNTY_A using Table Table 3.2.4.2-10 of Ref 4.

5. FIX_TYPE(1 bit)

If POS_TYPE(Position Result message) = 0x00 then

FIX_TYPE = 0

If POS_TYPE = 0x01 then

FIX_TYPE = 1

6. VELOCITY_INCL(1 bit), VELOCITY_HOR(9 bits), VELOCITY_VER(8 bits), HEADING(10 bits)

VELOCITY_INCL(IS801, 1 bit) = Bit 2 of OTHER_SECTIONS (Position Result message);

If VELOCITY_INCL = '1',

VELOCITY_HOR = scale_factor_hv x HOR_VEL(Position Result message)

scale_factor_hv = 0.0625/0.25 = 0.25;

Note: the range of VELOCITY_HOR is from 0 to 127.75 m/s, while the range of HOR_VEL is from 0 to 4095 m/s. Thus when HOR_VEL >= 2044 (127.75 m/s), VELOCITY_HOR = 511 ('111111111').

HEADING = scale_factor_heading x HEADING(Position Result message);

scale_factor_heading = $(360/2^{16})/(360/2^{10}) = 2^{-6}$;

Note: the range of HEADING(IS801) is from 0 to $360(1- 2^{-10})$ degrees, while the range of HEADING(F) is from 0 to $360(1- 2^{-16})$. Thus when HEADIND(F) >= 0xFFC0 (359.648375 degrees), HEADING(IS801) = '1111111111'.

If VELOCITY_INCL = '1' and FIX_TYPE = '1',

VELOCITY_VER(IS801, 8 bits) = VER_VEL(Position Result message);

If VELOCITY_INCL = '0' then the IS-801 "Provide Location Response" shall not include VELOCITY_HOR, VELOCITY_VER and HEADING parameters.

7. CLOCK_INCL(1 bit), CLOCK_BIAS(18 bits), CLOCK_DRIFT(16 bits)

CLOCK_INCL = Bit 3 of OTHER_SECTIONS (Position Result message);

If CLOCK_INCL = '1',

CLOCK_BIAS = scale_factor_clk_bias x CLK_BIAS(Position Result message) + offset_clk_bias;

Where,

scale_factor_clk_bias = 1e9; offset_clk_bias = 13,000 ns

Note: the range of CLOCK_BIAS is from -13,000 ns to 249,143 ns with a unit of 1 ns, while the range of CLK_BIAS is from – 429.287 seconds to 429.287 seconds with a minimum non-zero value of 100 ns and expressed in a "floating-point" format (defined in page 38 of Ref 2) with a unit of second. When CLK_BIAS < -13,000 ns, the CLOCK_BIAS is set to –13,000 ns. When CLK_BIAS > 249,143 ns, the CLOCK_BIAS is set to 249,143 ns.

CLOCK_DRIFT = scale_factor_clk_drift x CLK_DRIFT(Position Result message) ;

where

scale_factor_clk_bias = 1e3;

Note: the range of CLOCK_DRIFT is from –32768 ppb (ns/s) to 32768 ppb (ns/s) with a unit of 1 ppb (ns/s), while the range of CLK_DRIFT is from –327.52 ppm (us/s) to 327.52 ppm (us/s) with a minimum non-zero value of 0.0025 ppm and expressed in a "floating-point" format (defined in page 38 of Ref 2) with a unit of ppm (us/s). When CLK_DRIFT < –32768 ppb , the CLOCK_DRIFT is set to –32768 ppb. When CLK_DRIFT > 32768 ppb, the CLOCK_DRIFT is set to 32768 ppb.

If CLOCK_INCL = '0' then the IS-801 "Provide Location Response" shall not include CLOCK_BIAS and CLOCK_DRIFT parameters.

8. HEIGHT_INCL(1 bit), HEIGHT(14 bits)

HEIGHT_INCL = Bit 1 of OTHER_SECTIONS (Position Result message);

If HEIGHT_INCL = '1',

HEIGHT = scale_factor_height x HEIGHT(Position Result message)

scale_factor_height = 0.1;

Note: the range of HEIGHT(IS801) is from –500 m to 15833 m with the unit of 1 m, while the range of HEIGHT(Position Result message) is from –500 m to 6053.5m in units of 0.1m. Thus, the range of values beyond 6053.5m will never be used in the HEIGHT(IS801) parameter.

If HEIGHT_INCL = '0' then the IS-801 "Provide Location Response" shall not include HEIGHT parameter.

9. LOC_UNCRTNTY_V(5 bits)

If HEIGHT_INCL = '1',

LOC_UNCRTNTY_V = HEIGHT_STD_ER(Position Result message);

The conversions from HEIGHT_STD_ER to LOC_UNCRTNTY_V are based on Table 25 of Ref 2 and Table 3.2.4.2-10 of Ref 4. First the HEIGHT_STD_ER is converted to a number in an unit of meters by using Table 25 of Ref 2 and then mapping those numbers to a five-bit LOC_UNCRTNTY_V using Table 3.2.4.2-10 of Ref 4.

9 IS-801 Messages from PDE to CP

The CP shall convert the received IS-801 messages as described in this section.

9.1 Provide Base Station Almanac

The CP shall receive the IS-801 "Provide Base Station Almanac" message from the PDE in response to the IS-801 "Request Base Station Almanac". This message provides an alternative to IS-95 implicit method to obtain the approximate MS position data.

The message mapping from the IS-801 "Provide Base Station Almanac" to "F" interface "Approximate MS Position Response" is described in this section. The field names of "F" interface "Approximate MS Position Response" data are labeled with (F). The field names of the IS 801 "Provide Base Station Almanac" are labeled with (IS801)

1, MESS_ID[F]

MESS_ID (F) = the same value as in the latest "F" interface Approximate MS Position Request from SLC.

2. LAT[F, 32 bits]

LAT = scale_factor_lat x [LAT_REF(IS801, 23 bit) + DELTA_LAT(IS801, 16 bits)];

Notes:

a. LAT_REF is expressed as a two's complemented signed number. Its sign bit has to be extended to the 9 MSBs of a 32 bits (signed long) before computation is taken.

b. The unit for both LAT_REF and DELTA_LAT is 0.125 arc seconds and unit for LAT is $180/2^{32}$ degrees. Therefore

   scale_factor_lat = $(0.125/3600)/(180//2^{32})$;

c. If the field LOC_SAME_AS_PREV(IS801) is equal to 1, the previous base station's DELTA_LAT value shall be taken for the computation.

3. LON[F, 32 bits]

LON = scale_factor_lon x [LONG_REF(IS801, 24 bit) + DELTA_LONG(IS801, 16 bits)];

Notes:

a. LONG_REF is expressed as a two's complemented signed number. Its sign bit has to be extended to the 9 MSBs of a 32 bits (signed long) before computation is taken.

b. The unit for both LONG_REF and DELTA_LONG is 0.125 arc seconds and unit for LON is $360/2^{32}$ degrees. Therefore

   scale_factor = $(0.125/3600)/(360//2^{32})$;

c. If the field LOC_SAME_AS_PREV(IS801) is equal to 1, the previous base station's DELTA_LONG value shall be taken for the computation

4. ALT[F, 16 bits]

ALT = scale_factor_h x HEIGHT(IS801, 10 bits) + h_offset.

Notes:

a. The HEIGHT is in the range from 0 to 4092 m (in the unit of 4 m) and is expressed in 10 bits. In the computation, it needs to be converted to 16 bits unsigned integer type. The 6 MSBs shall be filled with 0s.

b. The ALT is in unit of 0.1 m and in the range from -500 m to 6053.5m. Therefore

Scale_factor_h = 4/0.1 = 40; and h_offset = 500/0.1 = 5000;

c. If the field LOC_SAME_AS_PREV(IS801) is equal to 1, the previous base station's HEIGHT value shall be taken for the computation.

5. EST_HOR_ER[F, 8 bits]

The CP shall set this field using the estimated horizontal error (1 sigma) and encode it following Table 48 of Ref 2.

9.2 Request Location Response

This message shall provide the MS position request information as part of the AI3 interface data.

The AI3 message structure is defined in Ref 3 section 7.2.1. The message mapping from the IS-801 "Request Location Response" to AI3 data structure is described in this section. The field names of AI3 data are labeled with (AI3). The field names of IS 801 Request Location Response are labeled with (IS801)

1. NUM_FIXES(AI3)

NUM_FIXES(AI3) = NUM_FIXES(IS801);

2. TIME_BTW_FIXES(AI3)

If T_BETW_FIXES (IS801) < 128, then

TIME_BTW_FIXES(AI3) = 2 x T_BETW_FIXES (IS801)

If T_BETW_FIXES (IS801) >= 128, then

TIME_BTW_FIXES(AI3) = 255

Note: both field are consist 8 bits. The scale factor of TIME_BTW_FIXES(AI3) is 0.5 seconds. The scale factor of T_BETW_FIXES (IS801) is 1 second. The range difference limited the ability of the SLC to handle the MS position request with T_BETW_FIXES(IS801) >= 128 seconds.

3. HORI_ERROR_MAX[AI3]

HORI_ERROR_MAX(AI3) = 0x07 (No maximum error limit).

4. VERT_TIME_MAX[AI3]

VERT_ERROR_MAX(AI3) = 0x07(No maximum error limit).

5. RESP_TIME_MAX[AI3]

RESP_TIME_MAX(AI3) = 111 (No time limit).

6. TIME_ACC_PRIORITY[AI3]

TIME_ACC_PRIORITY (AI3) = 0x00 (No priority imposed)

Note: The IS 801 Request Location Response also includes clock correction for GPS time and velocity information, but current version of SiRFLoc does not provide those supports. Therefore those requests are ignored implicitly.

9.3 Provide GPS Ephemeris

This message shall provide the ephemeris data as part of the AI3 interface data.

The AI3 message structure is defined in Ref 3 section 7.2.1. The mapping of IS-801 "Provide GPS Ephemeris" to AI3 data structure is described bellow. The field names of AI3 data are labeled with (AI3). The field name of IS 801 Provide GPS Ephemeris are labeled with (IS801)

Depending on the size of the ephemeris data set, the PDE may send the IS-801 "Provide GPS Ephemeris" in several parts. The total number of parts and the part number of the message are indicated in the elements of TOTAL_PARTS and PART_NUM, respectively. When CP receives all parts of the ephemeris data, it shall map them to AI3 structure as follows:

1. AB_PAR_INCL, ALPHA_0, ALPHA_1, ALPHA_2, ALPHA_3, BETA_0, BETA_1, BETA_2, and BETA_3 of AI3 data

The parameters AB_PAR_INCL, ALPHA_0, ALPHA_1, ALPHA_2, ALPHA_3, BETA_0, BETA_1, BETA_2, and BETA_3 of AI3 data are defined identically in the IS-801 "Provide GPS Ephemeris". If the AB_PAR_INCL[IS801] is equal to 1, the CP shall assign the AI3 parameters with the same values of the corresponding IS-801 data. Otherwise, the AI3 data shall not be changed

2. IONO_FLAG[AI3]

IONO_FLAG (AI3) = AB_PAR_INCL(IS801);

Note: IONOP_FLAG is 8 bits and AB_PAR_INCL is 1 bit. When AB_PAR_INCL is set to 1, IONO_FLAG = 1; When AB_PAR_INCL is set to 0, IONO_FLAG = 0;

The AI3 structure has 32 slots for storing the ephemeris data for each satellite. The slot sequence number shall match with the satellite PRN number (the maximum PRN number is 32). The ephemeris data of SV_PRN_NUM(AI3) shall be assigned to the ephemeris data of SV_PRN_NUM(IS801)

Most ephemeris parameters are defined identically in both AI3 and the IS-801 "Provide GPS Ephemeris". They can be copied directly from IS 801 to AI3 with the following exceptions

EPH_FLAG(AI3) = 1; valid ephemeris

SV_PRN_NUM(AI3, 8bits) = SV_PRN_NUM(IS801, 5bits) + 1;fill 0s in the 2MSBs

URA_IND(AI3) = 15; no accuracy prediction is available. IS801 does not contain this information;

OMEGADOT(AI3, 32 bits) = OMEGADOT (IS801, 24 bits); extend 24th bit to the 8 MSB of AI3 data;

IDOT(AI3, 16 bits) = IDOT(IS801, 14 bits); extend 14th bit to the 2 MSB of AI3 data;

AF0(AI3, 32 bits) = AF0(IS801, 22 bits); extend 22nd bit to the 10 MSB of AI3 data;

10 Theory of Operation

The CP shall interact with the SLC via the "F" interface messages. The CP shall send the AI3 data to SLC whenever the new AI3 data is available (without the request from SLC). There is no interaction between the CP and the SLC via the AI3 interface.

The IS-801 session of the CP may be opened before the SLC is powered on or before the SLC session (set with the AI3 interface flag) is opened. The SLC session shall be closed before the closing of the IS-801 session. When the IS-801 session is opened, the CP shall reset the AI3 data structure.

If the IS-801 session is opened before the SLC is powered on, the CDMA system time will be available before the CP is ready to perform the time transfer with the SLC. In this scenario, the CP may also get the approximate MS position data before the SLC is ready to send the "F" interface "Approximate MS Position Request" and hence the GPS performance of the SLC will be more optimized.

The CP can obtain the approximate MS position via either the IS-95 implicit method (from IS-95 "System Parameter Message") or the IS-801 messages (as described in 7.1.1). The IS-95 implicit method is considered to be the faster way of getting the BS position compared to the IS-801 messages. The IS-95 "System Parameter" is a required message to be sent to the CP from the BS during the CDMA MS Idle State, regardless of the IS-801 session. On the other hand, the IS-801 "Request/Provide Base Station Almanac" not only requires two interactive message exchange, but also will not invoked until the IS-801 session is opened.

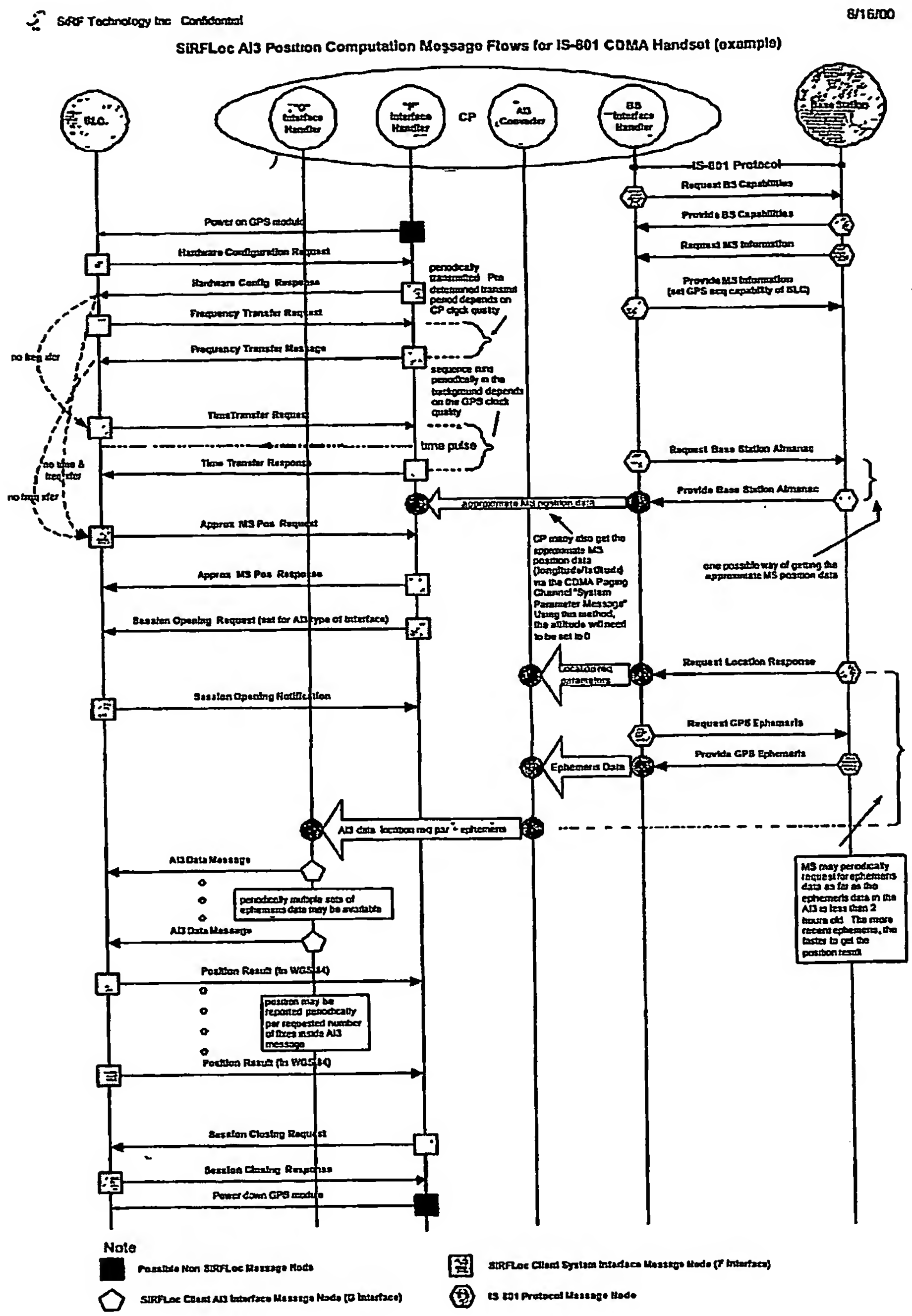
When the CP converted a complete new set of ephemeris data from BS via the IS-801 interface, the AI3 data is considered to be ready. The CP shall send the AI3 data to SLC less than 2 seconds after the AI3 data is ready, without the asking from the SLC. The CP should periodically request the BS to send the ephemeris data at a rate no longer than 2 hours. The faster the rate, the more optimized the GPS performance.

The SLC shall periodically send the position result to the CP via the "F" interface based on the number of position fixes as specified in the AI3 data structure. The CP shall set the number of position fixes in the AI3 structure even if the data is not available.

11 Message Flows

An example of AI3 message flows is presented in Figure 3.

Figure 3 – AI3 Message Flow for IS-801 Handset



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1 Scope

This document is to guide the designer of the Call Processing (CP) software for the implementation of the translation software to convert the RRLP protocol messages to SiRFLoc Aiding Independent Interoperability Interface (AI3) structure for a SiRFLoc based Mobile Station (MS).

The recommendation to be presented in this document can be implemented even by a non-GPS specialist.

This document only presents a recommended implementation for the customers to implement the AI3 architecture inside the CP software, but by no means represents the only implementation approach.

2 System Overview

The mobile station consists of a CP and a SiRFLoc Client (SLC). The CP refers to the dedicated hardware and software to establish and manage wireless communication with the base station. The SLC refers to the GPS section to receive GPS signals and determine the mobile station geographic location. It is composed of the "Aiding-Independent-Interoperability-Interface" layer, to dialog with the CP, on top of the SiRF GPS core technology.

Whereas SiRFLoc encompasses several architectures; the only one for which AI3 interface shall be used is the "Aiding Independent Interoperability Interface Architecture". The CP implements the Geolocation air-interface protocol (from Geolocation Server to CP) and then passes GPS aid information received from the base station to the SLC, over the AI3 as shown in Figure 1.

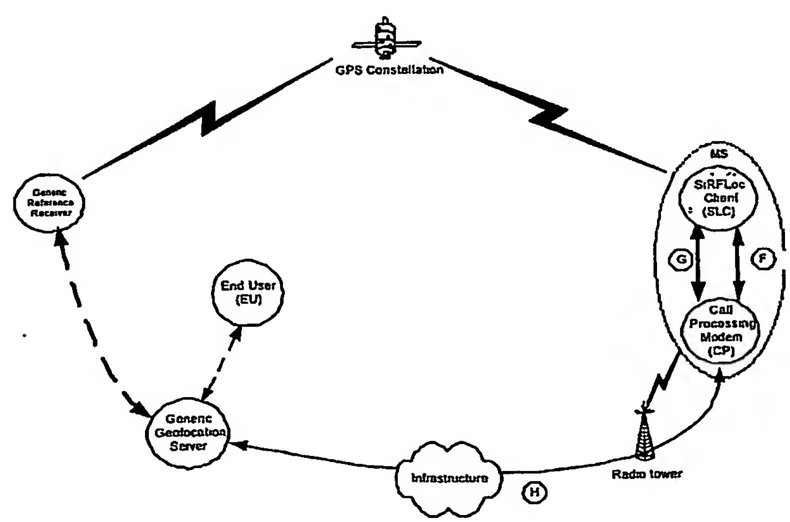

Figure 1 - Wireless Mobile Position System Architecture– AI3 Architecture

Table 1 describes the interfaces shown in Figure 1. There are different geolocation standards developed for different types of wireless networks; anyone can be the "H" interface.

Table 1 Interface Description

Interface	Functional Entities	Protocol	Description
H	Geolocation Server-CP	Air-interface	Various geolocation standards. Controlled by the CP manufacturer.
F	CP-SLC	SiRFLoc Specific	*SiRFLoc Client Interface Control Document*
G	CP-SLC	SiRFLoc Specific	*SiRFLoc AI3 Interface Control Document*

The F interface, which is the client system interface between SLC and CP, is defined in *SiRFLoc Client Interface Control Document*. It acts as a bootstrap protocol, ever present, allowing the CP to choose at run-time between an air-interface (case of the end-to-end system architecture) and the AI3. It is designed to perform the following tasks:

- SLC hardware management from the CP (power on/off, reset);
- If available, implicit aiding interface, i.e. time and frequency transfer from network (or from CP real time clock) via the CP, and approximate position (from the network, if it does exists),
- Session opening/closing (i.e. notifying the SLC that an air-interface connection has been opened/closed);
- In a dual-mode MS, notifying the SLC what air interface is on, and thus notifying the SLC what set of geolocation air-interface protocol to use to dialog with the SLS;
- Interfaces locally with the CP to allow the user to locally trigger a geolocation, and to report the position for display or usage at the MS;
- Convey the position results to the CP for MS local usage only.

In the "Aiding Independent Interoperability Interface Architecture", it is the CP developer's responsibility to implement the Geolocation protocol that is used between the Geolocation Server and CP. The G interface is used to convey position request and GPS aiding information received from the base station to the SLC. It is also used to report position results from SLC to PC.

Since there are many existing Geolocation protocols, the G interface is designed to be usable over a large range of Geolocation standards and air-interface independent, i.e. it

is unique for applicable air-interfaces. The "AI3" is actually a reduction of the applicable Geolocation standards. It will not be optimized for any of them.

The position results from SLC are conveyed to CP through both G interface and F interface for AI3 logical consistency and SLC client ICD consistency. The position results from AI3 interface shall be translated to RRLP position information and be passed to SMLC.

AI3 is an interface, not a protocol. There is a fundamental difference between an interface and a protocol. The *protocol* is an interactive process, where the information is explicitly requested and explicitly answered. Only the information really needed is requested. The mechanism of error detection and request for repetition is quite sophisticated. On the other hand, the *interface* does not imply any interaction between the two interfaced entities. All information has to be part of the message. There is no need for a sophisticated error correction scheme, and the size of the message can be quite large.

The AI3 shall be used exclusively between CP and SLC over a serial connection in the mobile station. It shall not be used over the air as the volume of exchanged information is quite significant.

3 Revision History

Revision	Date	Description	Editor
Revision 1.0	August 1, 2001	Initial official version	Q. John Zhang/Steve Chang

4 Glossary

2D Position. A two-dimensional (latitude and longitude) position.

3D Position. A three-dimensional (latitude, longitude, and height) position.

Aiding Independent Interoperability Interface (AI3). Generic aiding interface between CP and SLC, independent from the actual Geolocation protocol between Geolocation Server and CP.

Aiding Data. The data provided by the base station to the mobile station for various purposes (e.g., acquisition, location calculation or sensitivity improvement).

Generic Geolocation Server Station. This term refers to the entity in the network which provides aid (GPS-related or other) information to the SLC, and retrieves the position results. It has different names depending on the cellular platform of interest (SMLC for RRLP, GMLC for GSM,...)

Call Processor (CP). The dedicated hardware and software to establish and manage a wireless radio connection.

Ephemeris. The ephemeris data are embedded in the GPS Navigation Message. The precise (high accuracy) orbital parameters of one GPS satellite, as transmitted by that satellite in the GPS Navigation Message Subframe 1, 2, and 3. The ephemeris also includes satellite clock correction.

Geolocation. The process of determining a geographic location.

GPS. Global Positioning System.

ICD. Interface Control Document.

Mobile Station (MS). It consists of a CP and a SLC, communicates with the base station and receives GPS signals.

SiRFLoc Client (SLC). The SiRFLoc GPS section embedded in the mobile station. It is composed of a protocol layer, to dialog with the CP and SLS through the CP, on top of the SiRF GPS core technology (hardware and software).

SV. Space Vehicle or Satellite.

LCS: Location Service

SMLC: Serving Mobile Location Center

RRLP: Radio Resource LCS Protocol.

BTS: Base Transceiver Station

BSC: Base Station Controller

MSB: Most Significant Bit

LSB: Least Significant Bit

5 References

Ref 1 - ICD-GPS-200C, Navstar GPS Space Segment/Navigation User Interfaces, September 1997

Ref 2 - SiRFLoc Client Interface Control Document, Rev 1.4, May 4, 2001

Ref 3 – Aiding Independent Interoperability Interface Control Document, Rev 1.2, Aug, 2001

Ref 4 – 3GPP TS 04.31 version 8.5.0 Release 1999 – ETSI TS 101 527 V8.5.0 (2001-6), Radio Resource LCS Protocol

Ref 5 – GSM 01.04 version 7.0.0 release 1998, ETSI TR 101 748 V 7.0.0(1999-08), Abbreviations and Acronyms

Ref 6 – GSM 03.32 version 7.1.0 Release 1998, ETSI TS 101 109 v7.1.0 (2001-10)

Ref 7 - 3GPP TS09.31, version 7.5.0 (2001-5), Release 1998

6 Handset Design Concept with AI3 for GSM/3GPP

The purpose of the AI3 concept is to make the SLC based handset to work with any geolocation air-interface protocol for network aided data with or without SiRFLoc Server. The current AI3 architecture supports the network aiding with Ephemeris data or Almanac data.

Figure 2 shows the high level architecture of AI3 to be implemented inside the RRLP based handset. The CP shall communicate with the SLC via a RS232 link and hardware lines (for the time and frequency transfers) as described in Ref 2. The F and G are two separate logical channels for the RS232 interface. The G interface is designed to pass the AI3 aiding data to SLC. The rest of the aiding data will be passed to SLC via the F interface. On the SLC side, the F interface is a standard SiRFLoc client interface and the G interface is transparent to any standard air-interface protocols. The CP shall generate the AI3 data via an "RRLP message to AI3" converter. The AI3 data will be packed into the G message format via an AI3 interface message handler before passing to SLC via the RS232 link. The CP may obtain the time, and reference location data from an appropriate RRLP air-interface messages and pass them to SLC via appropriate "F" interface messages.

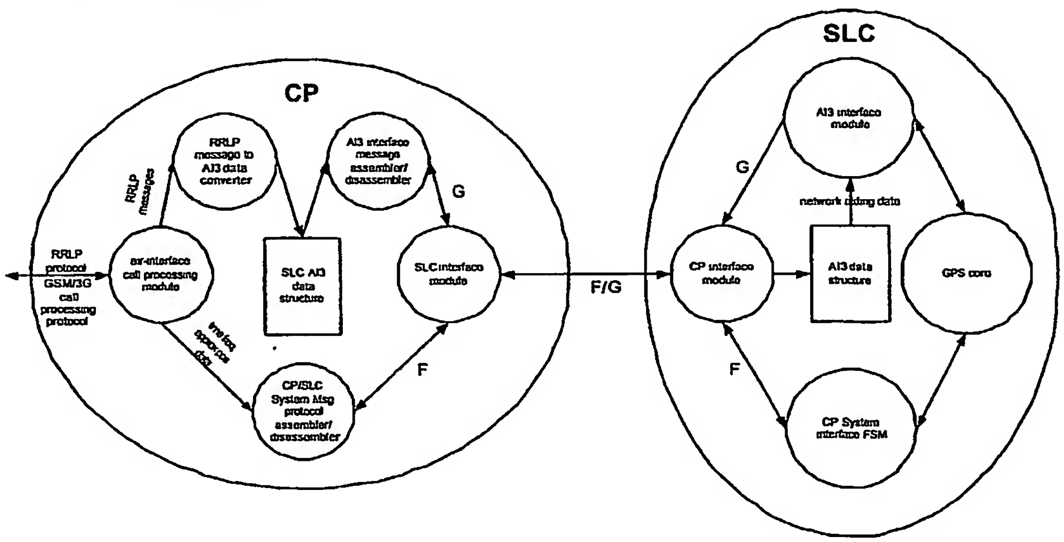

Figure 2 – General concept of AI3 architecture for RRLP based handset.

7 RRRLP Aiding Data and Responses versus the CP/SLC Interface Logical Channels

7.1 RRLP Aiding data receiving and transmitting

The RRLP messages can provide the aiding data required by the SLC for A-GPS position computation. The CP will pass the RRLP aiding data to SLC via the AI3 or F interfaces.

Table 2

Table 2- RRLP Aiding data and the corresponding aiding interface messages

RRLP Data Type	CP and SLC Logical Channel	Interface Message
Positioning Information – Response Time, Accuracy	G[AI3]	AI3 Request Message – Position Request QoS parameters
Reference Time – GPS time, GPS time of the week	F(SLC sysem)	Time Transfer Response Message.
UTC Model	F(SLC system)	Time Transfer Response Message.
Reference Location	F(SLC system)	Approximate MS Position Response Message.
Navigation Model – Ephemeris data	G(AI3)	AI3 Request Message – Eph data
IONO Model	G(AI3)	AI3 Request Message – IONO parameters
Almanac data	G(AI3)	AI3 Request Message – Almanac data

Table 2 lists the possible aiding data that may be provided by RRLP messages, but some of these data and other aiding data may also be obtained from the GSM or 3GPP Base Station via the standard GSM or 3GPP mobile telecommunication data messages. The method of obtaining the aiding data via the mobile data messages is beyond of the scope of this document.

7.2 AI3 response data and RRLP Response Messages

Table 3 lists the AI3 response data that will be provided by the SLC for RRLP response messages.

Table 3 – AI3 data to support RRLP Response Messages

7.3 Sample Messages Flows

Figure 3 shows the general idea of the A-GPS RRLP message flows for MS using AI3 based SiRFLoc Client.

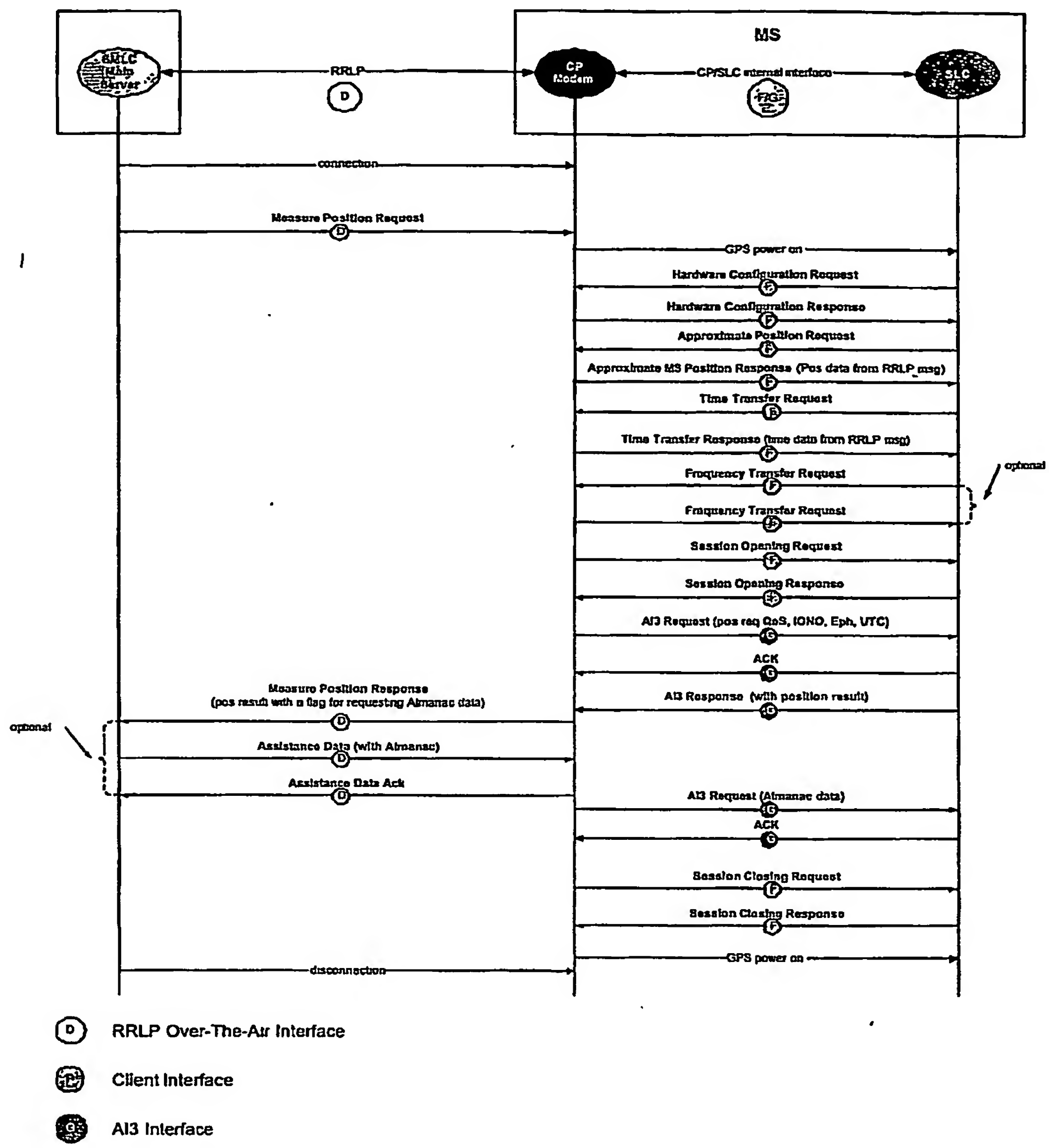

Figure 3 – Demonstration of RRLP to AI3 message flows

The purpose of this message flows is to demonstrate an example of the information transfer and it should not be interpreted as a procedure to be followed for implementation. In particular, the sequence of the messages flow for a location service can be different from the one illustrated.

1.) The CP may receive a location service request from the network via the RRLP Measure Position Request message before it starts the SLC.

2.) The CP will decode the Measure Position Request message and generate an AI3 data buffer for AI3 aiding. The CP may use the Reference Location data from the Measure Position Request message as the approximate position data for the F interface Approximate MS Position Response message. The CP may also use the Reference Time information from the Measure Position Request message as the time data for the F interface Time Transfer Response message. The CP will convert other aiding data such as the position request QoS parameters, the IONO parameters and the Ephemeris data into the internal AI3 data buffer. Notice that in this message flows, we assume that the Measure Position Request message does not contain the Almanac data.

3.) After recognizes the position request, the CP may start the SLC by powering on the GPS unit.

4.) The SLC shall first send the F interface Hardware Configuration Request message after the CP turns on the power of the GPS unit.

5.) The SLC will send an Approximate Position Request message after receiving the F interface Hardware Configuration Response message.

6.) The CP may choose to send the F interface Approximate Position Response message using the position data provided by the RRLP Measure Position Request message.

7.) The SLC may also sends the F interface Time Transfer Request message after receives the Approximate Position Response message from the CP.

8.) The CP may choose to send the F interface Time Transfer Response message using the time data provided by the RRLP Message Position Request message.

9.) The SLC may send the F interface Frequency Transfer Request message after receives the Hardware Configuration Response message from the CP.

10.) After sends the F interface Frequency Transfer Request message, the CP may send the F interface Session Opening Request message to SLC.

11.) The CP may send the G interface AI3 Request message after receives the F interface Session Opening Response message.

12.) The SLC always send the ACK or NACK message in response to the AI3 Request message.

13.) After computes the position result, the SLC will send the AI3 Response message to the CP. As part of the AI3 Response message, the SLC always provides the Almanac aging data.

14.) After receives the position result from the AI3 Response message, the CP may send the RRLP Measure Position Response message to the SMLC and request the Location Server to provide the Almanac data (if the CP decides the Almanac data in the SLC needs to be updated based on the Almanac aging data as provided by the SLC in the AI3 Response message).

15.) The CP will receive the Almanac data from the Location Server in the RRLP Assistance Data message.

16.) The CP will send the Almanac data to SLC for Almanac update inside the GPS unit via an AI3 Request message (contains only the Almanac data).

17.) The SLC will send the ACK after successfully receives the Almanac data.

18.) The CP may choose to close the location service by sending the F interface Session Closing Request message to SLC.

19.) The SLC will send the F interface Session Closing Response message to CP after finishes the house keeping for session close.

20.) The CP may choose to turn off the power of the GPS unit after receives the F interface Session Closing Response message.

8 RRLP Aiding Data Conversion to AI3 and F interface messages

There are two RRLP components from SMLC to MS are needed for MS based GPS positioning. They are "positionInstruct" and "gps-AssistData". The "positionInstruct" is a mandatory field of "measure position request". The "gps-AssistData" is an optional field for both "measure position request" and "Assistant Data".

8.1 Position Instructions

For supporting AI3 operation, the RRLP "position instructions" must has its "method type" set to value of 1, 2, or 3 (MS based, MS based is preferred or MS based is allowed) and its "positioning method" set the value of 1 or 2 ("GPS" , or "E-OTD or GPS"). The "PositionInstruct" provides some of the parameters of AI3 "position request". The rest of them need to be filled with defaulted values.

1. NUM_FIXS (AI3)

RRLP does not have this information field and is not able to request multiple MS position. The value of NUM_FIXS shall set to 1.

2. TIME_BTW_FIXES(AI3)

This field indicates the time between two consecutive position fixes. Since RRLP can only request one MS position fix, this value shall set to 0.

3. HORI_ERROR_MAX (AI3)

This field provides the maximum requested horizontal error with a 95% of the cases having an error less than this value. The 7-bit "accuracy" field of the RRLP "positioning instructions" provides requested one sigma value of the horizontal error for the position. Table 1 of Ref. [6] (GSM 03.32) and Table 6 of Ref. [3] (AI3 ICD) provide the error codes for the two protocols, respectively. In two-dimension cases, the probability of the position within one sigma ellipse is 39%. To increase the probability to 95%, the error range need to be increased by 2.45 times. That is

$$HORI\_ERROR\_MAX(AI3) = 2.45 \times accuracy(RRLP)$$

Table 4 gives the error code matches between the two protocols

Table 4. AI3/ RRLP Position Error Conversion

AI3 HORI_ERROR_MAX value	RRLP 7-bit Uncertainty code
0x00	0x00
0x01	0x01 and 0x02
0x02	0x03
0x03	0x04 to 0x07
0x04	0x08 to 0x0A
0x05	0xB to 0x0F
0x06	0x10 to 0x15
0x07	0x16 to 0x7F
0x08-0xFF (Reserved)	0x80 to 0xFF (invalid)

4. VERT_ERROR_MAX (AI3)

Since the RRLP positioning instructions do not provide vertical positioning error request, the AI3 VERT_ERROR_MAX shall be filled with the value of 0x07 indicating no maximum error limit.

5. RESP_TIME_MAX(AI3)

The AI3's RESP_TIME_MAX and RRLP positioning instructions' "response time" are defined in the same way. The "response time" value shall be set to the same value of RESP_TIME_MAX.

6. TIM_ACC_PRIORITY (AI3)

This parameter provides an instruction for SLC to choose priority when response time and location accuracy requests are contradicting But RRLP MsrPosition-Req does not provide this kind of dictation. SLC is required to make its own decision to meet both time and accuracy requirements. This value shall be set to 0x00.

8.2 GPS-AssistData

The "GPS assistant data", which can be a component of RRLP or a field of the positionInstruct component of RRLP, provides ionospheric model, navigation model and almanac to SLC through G (AI3) interface. It also provides reference location and reference time to SLC through F (SLC system) interface.

1. IONO_FLAG (AI3)

When ionospheric model is available in the RRLP GPS assistant data, the IONO_FLAG shall be set to 1, otherwise it shall be set to 0;

2. ALPHA_0 to Beta_3 (AI3)

The AI3 parameters of ALPHA_0 to Beta_3 and RRLP ionospheric model α_0 and β_0 have exactly the same definitions. The values of α_0 and β_0 shall be directly assigned to ALPHA_0 to Beta_3.

3. EPH_FLAG(AI3)

   The AI3 structure has 32 slots for storing the ephemeris data , one for each satellite. The PRN number (1 to 32) of the satellite shall match with the slot sequence number (1 to 32). When a valid ephemeris of a satellite is available the EPH_FLAG shall be set to 1; otherwise the EPH_FLAG and the whole slot are set to 0; To be considered as a valid ephemeris data, all the 6 bits of the "SV health" in the navigation model (RRLP) must be 0; otherwise the ephemeris data shall be considered as an invalid ephemeris.

4. Ephemeris Parameters for Each Satellite (AI3)

   Most ephemeris parameters are defined identically in both AI3 and the RRLP "navigation model". They can be copied directly from RRLP to AI3 with the following exceptions.

   SV_PRN_NUM(AI3, 8bits) = SatID(RRLP, 6bits) + 1; fill 0s in the 2 MSBs.

   URA_IND(AI3, 8 bits) = URA index (RRLP, 4 bits); fill 0s in the 4 MSBs.

   IODE(AI3, 8 bits) = 8 LSBs of the 10 bit IODC (RRLP, 10 bits)

   OMEGADOT(AI3, 32 bits) = OMEGAdot (RRLP, 24 bits); extend 24th bit to the 8 MSBs of OMEGADOT;

   IDOT(AI3, 16 bits) = Idot(RRLP, 14 bits); extend 14th bit to the 2 MSBs of IODT;

   AF0(AI3, 32 bits) = af_0(RRLP, 22 bits); extend 22nd bit to the 10 MSBs of AF0;

5. ALM_DATA_FLAG (AI3)

   This field indicates whether the almanac information is available in the AI3 structure or not. When it is available, this field shall be set to 1, otherwise it is set to 0.

6. ALM_WEEK_NUM (AI3)

   This field shall be set to the same value of WNa (RRLP)

7. ALM_VALID_FLAG (AI3)

   The AI3 structure has 32 slots for storing the almanac data, one for each satellite. The satellite PRN number (1 to 32) shall match with the slot sequence number (1 to 32). When a valid almanac of a satellite is available the ALM_VALID_FLAG is set to 1; otherwise the ALM_VALID_FLAG and the whole slot are set to 0; To be considered as a valid ephemeris data, all the 8 bits of the "SV health" in the almanac (RRLP) must be 0, otherwise the almanac data shall be considered as an invalid almanac

8. Almanac Parameters for Each Satellite (AI3)

Most almanac parameters are defined identically in both AI3 and the RRLP. They can be copied directly from RRLP to AI3 with the following exceptions.

ALM_SV_PRN_NUM(AI3, 8bits) = SatID(RRLP, 6bits) + 1; fill 0s in the 2 MSBs.

ALM_AF0 (16 bits) = af_0 (RRLP, 11bits), extend 11^{th} bit to the 5 MSBs of ALM_AF0.

ALM_AF1 (16 bits) = af_1 (RRLP, 11bits), extend 11^{th} bit to the 5 MSBs of ALM_AF1.

9. Approximate MS Position Response (F Interface)

The "Reference Location" field of the "GPS Assistance Data" element of RRLP provides information required by "Approximate MS Position Response" (F Interface message).

LAT (F) is a 4-byte two's complement binary number. It ranges from −90 degrees to $90(1-2^{-31})$ degrees. The latitude defined in RRLP is a 3-byte parameter ranging from −90 degree to $90(1-2^{-23})$ degrees with its first bit as sign bit and the rest of 23 represent the absolute value of the latitude. The equation (1) shall be used for conversion.

$$LAT = sign \times (N + 0.5) \times 2^8 \qquad (1)$$

Where N is the coded number of the 23 bits latitude (RRLP), the sign is equal to 1 when the sign bit (RRLP) is 0 (North) and it is equal to −1 when the sign bit(RRLP) is 1 (south). Since the LAT(F) has a higher resolution than the "latitude"(RRLP) and the actual absolute value of latitude is between N and N+1, the value of 0.5 is added to achieve statistic balance.

LON (F) is a 4-byte two's complement binary. It ranges from −180 degrees to $180(1-2^{-31})$ degrees. The longitude is coded in two's complement binary on 24 bits. It covers the same range. The equation (2) shall be used for the conversion.

$$LON = (N + sign(N)0.5) \times 2^8 \qquad (2)$$

Where the N is the number of the 24 bits longitude (RRLP), sing(N) is equal to 1 when N is a positive number and it is equal t −1 when the N is a negative number. Since the LON(F) has a higher resolution than the "longitude"(RRLP) and the actual value of longitude is between N and N+1, the value of 0.5 is added to achieve statistic balance.

ALT(F) is a 2-byte number in unsigned binary offset coding, ranging from −500 meters to 6053.5 meters in unit of 0.1 meters. The altitude of RRLP is a tew bytes parameter. The MSB in the most significant byte presents the direction, 0 for height, 1 for depth. The 15 LSBs are absolute value of the altitude encoded in increments of 1 meter. When the altitude is from −500 meters (500 meters in depth) to 6053.5 meters (6053.5 meters in height), the conversion shall be

$$ALT = sign \times N * 10 + 5000 \qquad (3)$$

The value of "sign" is 1 when the direction bit (RRLP) is 0 (height) and it is −1 when the direction bit is 1 (depth). The N is the binary number of the 15 LSBs.

When the altitude is deeper than 500 meters in depth, ALT = 0x00; When the altitude is higher than 6053.5 meters the ALT = 0xFFFF;

EST_HOR_ER (F) is the estimated horizontal error for the approximate MS position. Since the RRLP reference location does not provide its uncertainty, this 1 byte parameter shall set to 0xFF. If the RRLP GPS assistance data provider uses the serving BTS position as the approximate MS position, the Timing Advance parameter can be used to estimate the maximum distance between the serving BTS and the MS, which can be used for the EST_HOR_ER.

10. Time Transfer Response (F)

RRLP reference time fields specify the relationship between GPS time and air-interface time of the BTS transmission in the reference cell. Together with the Timing Advance (signal propagation round-trip delay between the MS and BS), it provides MS the ability to compute GPS time and synchronize MS clock to GPS time frame. See Ref [2] for detailed method and algorithm for time transfer from CP to SLC. Note, the GPS_WEEK_NUM(F) is the absolute week number and the "GPS Week" of reference time (RRLP) has short week number format with modulo of 1024. Currently, before next rollover (in the year of 2019),

GPS_WEEK_NUM(F) = GPS Week (RRLP) + 1024;

The time transfer response (F) message also includes DELTA_UTC, this information can be obtained from UTC model (RRLP). See Ref. [1], section 20.3.3.5.2.4 for computing DELTA_UTC.

Note: For iDEN and 3G wireless networks, precise GPS time is available at the CP and the "reference time" (RRLP) message may not be needed for time transfer.

11. Frequency Transfer Response (F)

RRLP GPS assistance data does not provides reference frequency information. MS synchronize its frequency with BTS through frequency correction burst. See Ref [2] for details on frequency transfer from CP to SLC.

9 RRLP Messages from MS to SMLC

In response to SMLC's "measure position request", the MS send "measure position response" message to SMLC. and send it to SMLC. This "measure position response" shall include "LocationInfo" element in the case of MS based GPS location method.

9.1 Location Information Element (RRLP)

When the CP receives the "position result" from the SLC and its "position status" field is 0x01 (position information available), it shall convert the "position result" (AI3) into "locationInfo" (RRLP).

1. GPS TOW (RRLP)

The 24 bits of GPS TOW of location information (RRLP) are the LSBs of GPS time of week. Both the "GPS TOW" (RRLP) and the "MEAS_GPS_SECONDS" (32 bits, F) are in the unit of milliseconds. The "GPS TOW"(RRLP) shall be equal to the 24 LSBs of the "MEAS_GPS_SECONDS"(AI3). The MSBs shall be derived by the SMLC to unambiguously derive the GPS TOW.

2. Fix Type(RRLP)

   Fix Type(RRLP) = POS_TYPE(AI3)

3. Position Estimate (RRLP)

The position estimate allows several shapes. Which shape shall be used is dependent the data availability indicated in "OTHER SECTIONS" field of "Position Results"(AI3). Table 5 shows their relationship.

Table 5. Shapes of Location Estimates

Values of OTHER_SECTIONS (AI3)	Shapes of Location Estimate (RRLP)
0x00	Ellipsoid Point
0x01	Ellipsoid Point with Uncertainty Ellipse
0x02	Ellipsoid Point with Altitude
0x03	Ellipsoid Point with Altitude and Uncertainty Ellipsoid

The parameter conversions from "Position Results" to "Location Estimate" are listed here.

- The latitude defined in RRLP(Ref. [6]) is a 3-byte parameter ranging from –90 degree to $90(1- 2^{-23})$ degrees with its first bit as sign bit and the rest of 23 represent the absolute value of the latitude. The MEAS_LAT is a 32 bits Two's complement value of the latitude ranging from –90 degrees to $90(1- 2^{-31})$ degrees. The value of the 23 LMBs of the latitude (RRLP) shall equal to the absolute value of MEAS_LAT (AI3) divided by 2^8. The MSB of the most significant byte of latitude (RRLP) shall equal to the MSB of the most significant byte of the MEAS_LAT (AI3).
- The longitude defined in Ref. [6] is coded in two's complement binary on 24 bits. It covers the range from –180 degrees to +180 degrees. MEAS_LONG (AI3) is a 4-byte two's complement binary. It ranges from –180 degrees to $180(1- 2^{-31})$ degrees. The conversion should be

  24-bit longitude of RRLP = 24 bits MSBs of the 32-bit MEAS_LONG
- The values of AI3's MAJ_STD_ER and MIN_STD_ER shall be derived from Table 13 and 14 of the Ref. [3] and converted to the 7-bit "uncertainty semi-major" and 7-bit "uncertainty semi-minor" of RRLP according to section 6.2 of the Ref. [6]

- Orientation of the major axis (RRLP) is a 8-bit binary number in a unit of 2 degrees in the range of 1 to 179 representing angle ranging from 0 to 360 degrees. The ER_EL_ANG(AI3) is a 8-bit binary number in the unit of $180/2^8$.

  Orientation (RRLP) = ER_EL_ANG(AI3) $\times 180/2^9$.

- For the shape of Ellipsoid Point with Uncertainty Ellipse, the parameter of "confidence" shall be filled by number of 39. For the shape of Ellipsoid Point with Altitude and Uncertainty Ellipsoid, the parameter of confidence shall be filled by number of 20.

- The "altitude" (RRLP) is encoded in increments of 1 meter using 15 bit binary coded number N. There is a direction bit, 0 for height, 1 for depth. The HEIGHT(AI3) is a 2-byte number in unsigned binary offset coding, ranging from –500 meters to 6053.5 meters in unit of 0.1 meters. The conversion shall be

$$N = \left|(HEIGHT - 5000)/10\right| \tag{4}$$

  When the HEIGHT is less than 5000, the direction bit of the altitude shall be set to 1 (depth), otherwise it shall be set to 0 (height).

- The "Uncertainty Altitude" (RRLP) is the uncertainty in altitude coded in 7-bit binary number. The coding method is described in section 6.4 of Ref. [6]. The HEIGHT_STD_ER (AI3) is coded in an 8-bit binary number. The coding method is defined in Table 15 of Ref. [3]. First, the 8-bit HEIGHT_STD_ER shall be converted to a value in meters and then it shall be coded to the 7-bit Uncertainty Altitude.

9.2 Location Error Information Element (RRLP)

When the CP receives the "position results" from the SLC and its "position status" field is 0x00 (position error information), a position error is reported The position error field shall be mapped to Location error information element of RRLP. When the reason of the position error is "need more time", the CP shall wait for the position results for a predetermined time, usually the "response time" of the position instruction. At the end of that time if CP does still not receive the position results, it shall send a location error information element to SMLC with a location error reason of "undefined error).

Table 6 Location Error Reasons

Error Descriptions	Position error (AI3)	Error Reason (RRLP)
Not enough GPS satellites	0x00	1
GPS assistance data missing	0x01	6
Need more time	0x03	0 (undefined error)
Time out	0x04	8.

10 Theory of Operation

The CP may start the SLC at any time in the following possible choices:

The CP shall interact with the SLC via the "F" interface messages for system configuration information exchange, geo-location session management, and time and frequency transfer. The approximate MS position information is also passed to SLC through F interface.

The RRLP session of the CP may be opened before the SLC is powered on or before the SLC session is opened. The SLC session shall be closed before the closing of the RRLP session. When the RRLP session is opened, the CP shall reset the AI3 data structure.

If the RRLP session is opened before the SLC is powered on and all the information, such as time, frequency and approximate MS position, are available before SLC requesting for them, the GPS performance of the SLC will be more optimized.

When the CP converted a complete new set of GPS assistance data or Measure position request from SMLC via the RRLP interface, the AI3 data is considered to be ready. The CP shall send the AI3 data to SLC less than 2 seconds after the AI3 data is ready, without the asking from the SLC. The SLC shall periodically send the position result to the CP via the "AI3" interface based on the number of position fixes as specified in the AI3 data structure. The CP shall set the number of position fixes in the AI3 structure according to the contents of measure position request message from SMLC.

11 Message Flows

An example of AI3 message flows is presented in Figure 4.

Figure 4 – AI3 Message Flow for RRLP Handset